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INTERSTATE ATMOSPHERIC TRANSPORT OF TRACER PARTICLES IN THE NEW YORK-NEW JERSEY METROPOLITAN AREA

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Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

January 1958

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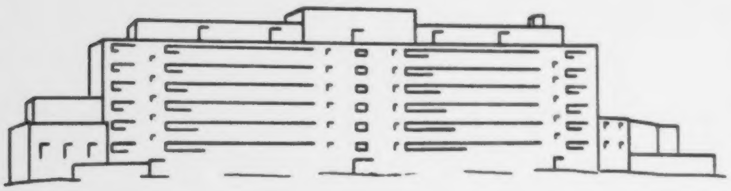

INTERSTATE ATMOSPHERIC TRANSPORT OF TRACER PARTICLES IN THE N. Y. - N. J. METROPOLITAN AREA

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121

INTERSTATE ATMOSPHERIC TRANSPORT OF TRACER PARTICLES IN THE N.Y.-N.J. METROPOLITAN AREA

A report to the Interstate Sanitation Commission of New York, New Jersey, and Connecticut on investigations conducted in cooperation with the Commission as part of the New York - New Jersey Interstate Air Pollution Study, 1956-1957.

William H. Megonnell, Sanitary Engineer
Community Air Pollution Program

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Bureau of State Services
Division of Sanitary Engineering Services

Robert A. Taft Sanitary Engineering Center
Cincinnati 26, Ohio

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I

CONTENTS

Page

PREFACE 1

ACKNOWLEDGEMENTS FROM INTERSTATE SANITATION COMMISSION 3

SUMMARY AND CONCLUSIONS 5

INTRODUCTION 15

PROJECT PLANS AND METHOD OF OPERATIONS 17

- Tracers 17
- Objective and Scope 18
- Meteorology 20
- Dispersal of Tracer Material 22
- Sampling 26
- Preparing Sampling Media for Field Use 31
- Assessment of Samples 32

CONTAMINATION, BACKGROUND AND CONTROL SAMPLES 34

PUBLIC INFORMATION 38

DEMONSTRATION PROJECT GRANT 38

PHASE I 40

- Scheduling 40
- Dissemination Points 41
- Sampling Network 43
- Project Meteorological Station 46
- Field Headquarters 49
- Sampling Operations 50
- Test Results 51
- Discussion of Results 59

PHASE II 72

- Scheduling 72
- Dissemination Points 73
- Sampling Network 74
- Meteorological Coverage 77
- Field Headquarters 78
- Sampling Operations 78
- Test Results 79
- Discussion of Results 81

REFERENCES 90

APPENDIX 91

NOTE

This report was assembled from the best
available preprinted text.

PREFACE

The fluorescent-particle tracer technique discussed in this report is not particularly new. Research on the method and materials, and the development, calibration and evaluation of specialized equipment were done by others, especially by the Department of Chemistry of Stanford University.

To the writer's knowledge, the technique previously had its greatest application in the evaluation of pollutant dispersal from specific industrial plants and in meteorological studies to investigate the travel of air parcels over long distances.

Employment of the method in the atmospheric transport project of the New York-New Jersey Interstate Air Pollution Study, it is believed, represents its first adaptation to an extensive metropolitan-area survey The project was planned as a minimum expense undertaking commensurate, of course, with attainment of the desired objective. It was felt that experiences gained during this project might be of interest and assistance to others desiring to employ the tracer technique

Therefore, an attempt was made in this report to include as much detail as possible on the operation, its administrative and public-relations problems, as well as technical difficulties--perhaps at the risk of including apparently insignificant and minor points. The information is indicative of some of the various problems encountered. It is hoped that it may prove to be of value to persons charged with organizing and conducting similar studies in the future.

ACKNOWLEDGEMENTS

FROM

INTERSTATE SANITATION COMMISSION

The Interstate Sanitation Commission is sincerely grateful for the assistance rendered by many agencies and individuals toward the success of this project. All of the numerous participants and contributors cannot be listed, but special acknowledgement is due the following individuals and organizations:

U. S. Army Chemical Corps, Research and Development Command, Assessment Division, Biological Warfare Laboratories, Fort Detrick, Maryland: Mr. John T. Quynn, Dr. Edwin L. Cox, and Mr. Earl Bachtell.

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Mr. D. Richard Simeone, Health Officer, Cliffside Park, New Jersey

U. S. Public Health Service Hospital, Stapelton, Staten Island, New York.

Honorable John R. Armellino, Mayor, West New York, New Jersey.

Phase I Route Captains: Messrs. Anthony N. Ameduri, Jr., Louis Ameduri, Rocco Ameduri, Frank Hauber, Frank A. Hauber, Donald Horan, David N. Miller, William E. Miller, Joseph Polly and John W. Russell, Jr.

Phase II Route Captains: Messrs. Joseph J. Bonadio, Jr., Ralph Calabrese, John McCaskey, D. Richard Simeone, Joseph J. Spincola, Jr., and Walter C. Brewer.

Phase I and Phase II sampling - site volunteers listed in the Appendix.

Miss Anne R. Kelly, Owner, Staten Island Airport property.

Mr. George L. Wasser, Field Engineer of the Commission staff, served as Assistant Project Officer. Another Commission employee, Mr. Emanual G. Katsoulis, operated the dissemination equipment.

SUMMARY AND CONCLUSIONS

The purpose of this project was to investigate the interstate transport of air pollutants in the New York-New Jersey area. Small amounts of an identifiable simulated atmospheric pollutant (fluorescent zinc cadmuim sulfide tracer material) were released in one State and recovered in the other. In Phase I, the tracer was dispersed in the air at various points in New Jersey and was recovered in Staten Island. In Phase II, the material was released in Manhattan and collected in New Jersey.

The interstate-transfer potential of air pollutants, in both directions, between the States of New Jersey and New York was clearly demonstrated. Dispersal patterns and flight paths of the tracer material were determined. Previous studies had indicated that the tracer particles behaved similarly to the molecules of the air mass in which they were entrained. Therefore, it is reasonable to expect that dispersal of actual air contaminants in the area would be analogous to that of the tracer particles

To determine what effect, if any, topography might have on windflow, the sampling networks in both phases were based largely on topographical features of the collection areas. In choosing sites for dispersal of the tracer, no attempt was made to select known or suspected sources of interstate air pollution.

In the establishment of sampling stations, consideration was given to the character of the particular locality. Thus, in Staten Island, where there were extensive suburban and rural areas and practically no tall buildings, all samplers were supported about five feet above the ground. Lofty apartment houses, hotels, and other tall structures were located in portions of the New Jersey sampling area so samplers were installed at various heights. Locations from 5 to 80 feet above the ground were used, to detect any elevational differences in diffusion of the tracer.

Of five planned phases, two were undertaken, and in the second of these, only a few tests could be conducted before termination of the study. Satisfactory wind direction was the sole criterion upon which testing was based. Nevertheless, an average of 7 days was encountered between tests in the first phase and, in Phase II, the average was 14 days.

Field operations were conducted from May 28 to November 27, 1957. Of 21 tests in Phase I, 12 yielded reliable data. Four tests, two of them successful, were conducted in the second phase. Unsuccessful tests were attributable to factors such as contamination of filters, inaccurate or marginal forecasts, and failure of communications between the headquarters and field personnel.

Generally, the tests in Phase I were conducted when air pollution, as determined by subjective observation, was not severe. Nevertheless, when wind directions were satisfactory, significant amounts of the tracer were collected in Staten Island. This demonstrates the movement of air pollution from New Jersey to New York.

Run No. 21 was the only test in Phase I which was conducted during an atmospheric temperature inversion, and recovery of the tracer was significantly higher in this test than in the others. There was a 4°F inversion from the surface to 900 feet. It is estimated that 5.28 per cent of the dispersed tracer material traveled across a portion of Staten Island, within six feet of the ground(considered man's normal habitat), during this test. As would be expected, this confirms that the dispersal in Staten Island of pollutants from New Jersey is more of a problem during temperature inversions. But the maximum value found during the tracer project cannot be considered an absolute maximum; far higher amounts would probably have been recovered under different, more severe atmospheric conditions.

In planning Phase II, it was intended that east-to-west movement of the tracer would be investigated. Easterly components of the winds, however, were not strong in this phase. Consequently, travel of the tracer nearly paralleled the sampling routes, rather than crossing them transversely. Primarily for this reason, the percentages of dispersed material which passed through the Phase II sampling area would be difficult to compute. The amounts recovered were considerable, however, and indicate that the dispersion in New Jersey of air pollutants from New York also is a significant problem. Additional testing in this area, under a variety of atmospheric conditions, would be highly desirable.

These tracer results are indicative of the interstate dispersal of air pollutants in both directions, depending on the course of the wind, between New Jersey and New York. To arrive at an estimate of the magnitude of the problem, it would be necessary merely to relate the tracer results to actual air pollution emissions in the respective states.

Some interesting topographical influences on the movement of air masses were noted. Although there were exceptions, particularly in Phase I, filters exposed at stations in the high-ground-elevation routes generally contained a greater number of fluorescent particles than samples obtained from stations in the low-level sampling lines. This can probably be attributed largely to mechanical uplift of the air masses by the local terrain.

Air masses were definitely deflected by the New Jersey Palisades, which channeled winds along the Hudson River.

When the winds are similar to those which existed during tests in the second phase of this project, it is likely that this phenomenon reduces the extent of travel of New York pollutants into New Jersey. With a strong easterly component to the wind, however, this topographical effect would probably be considerably less pronounced.

To a much lesser degree, a topographical influence on windflow was discernable in Staten Island during certain of the tests in that area. There appeared to be channeling of air masses through the lowest portion of the Island when the winds were from certain directions.

In New Jersey, where samplers were located at various elevations, no significant difference was found between fluorescent-particle recovery by adjacent low-level and high-level samplers within a particular sampling route. This demonstrates the homogeneity and thorough mixing of the tracer in the atmosphere and indicates that there was considerable diffusion vertically as well as horizontally.

Throughout both phases, positive filters were occasionally obtained at stations which were far removed from the general trajectory path. In some cases, because of clumping of particles on the filters, rather than the characteristic random distribution of the airborne tracer, these could be definitely attributed to contamination; at other times, contamination was not evident. It is possible that, due to variability or gustiness of the wind, a parcel of air may have strayed from the main mass and carried fluorescent particles to stations outside the main path of travel. Background fluorescence naturally present in the atmosphere and improper assessment of filters are other possibilities. In the absence of additional enlightening data, however, it does not appear profitable to speculate on the source of these counts.

Each test was a separate case in itself and depended on wind and atmospheric conditions during the test. Reproduction of the results would be largely a matter of chance, for examination of the test results failed to reveal any striking relationships between dispersal patterns or amounts of tracer material recovered and the parameters of wind direction and speed. Similarly, tracer recovery could not be related to the amount of fluorescent material released. Temperature-lapse data, while probably essential, were inadequate for analyses along these lines.

Interstate transfer, in both directions, of the tracer material was demonstrated, and, based on previous studies, it is believed that actual air pollutants behave in an analogous manner. But no general conclusions are evident from the test results to permit prediction, under specific conditions, of the rate of diffusion and extent of travel in one State of pollutants from the other State.

Besides the immediate objective concerning the dispersal of interstate air pollutants in the New York-

New Jersey area, this project served to evaluate and demonstrate the potentiality of the tracer technique in area air-pollution surveys of this sort. It is concluded that the method is useful in determining the trajectory and distribution of pollutants under different meteorological conditions.

Although several theoretical relationships have been advanced for predicting the rates of diffusion and travel of atmospheric pollutants, they have been confirmed by experiment under only a limited number of idealized conditions. They are, therefore, of questionable value over the wide range of topographical and meteorological conditions usually encountered.

Much of the uncertainty associated with the theoretical equations can be eliminated by use of the tracer technique. Tracer results are direct and are determined almost entirely by meteorological conditions existing during a particular test. Significance of the resulting data can be determined with more certainty and with far less supplementary meteorological information than would be necessary if the diffusion and travel of atmospheric pollutants were to be evaluated by the extant theories in this field.

This project, of necessity, was not intended as an exhaustive investigation of pollution-dispersal patterns in the New York-New Jersey area. Its scope was limited primarily by the relatively short time that was available. Field tests were made under a few of the countless possible meteorological combinations. A limited number of dissemination points was used, and no attempt was made to choose sites near known or suspected pollution sources. The value of the test method, however, seems to have been demonstrated.

One particularly attractive feature of the method is the simplicity with which results can be presented, especially to the layman. Maps can easily be drawn to indicate, by means of different shading or coloring between the iso-lines, the orders of magnitude of tracer recovery. Such uncomplicated presentation is clear and easily understood. It can be of inestimable value in demonstrating pollutant dispersal to nontechnical persons, who might become confused by and fail to grasp the significance of similar data presented in the jargon of the technologist.

For closer conformity to and evaluation of actual conditions, extensive additional testing would have to be undertaken. Tracer material should be released closer to actual pollution sources, perhaps at various points and different elevations simultaneously. Seasonal, diurnal, and nocturnal variations, the influence of winds from various directions and at different speeds, the effects of atmospheric stagnations and severe inversions, and a number of other factors should be considered in a comprehensive study. Obviously, this would be a long-range and costly program.

Incidental Findings outside the Scope of the Project

Several incidental observations made during field operations, while not directly pertinent to the tracer project, were of interest and importance in the overall study of air pollution in the New York - New Jersey area.

In Staten Island, it was found that rubber tape and tubing exposed to the atmosphere at sampling stations rotted and cracked badly at every point of stress. Excessive rubber deterioration was not noted in the New Jersey sampling area. This observation indicated that ozone (oxidants) was probably a problem in Staten Island, but not in New Jersey, and it led to additional testing for this contaminant.

Phase I filters were, in general, various shades of gray, black filters were rare and could usually be traced to local pollution sources. In Phase II, however, practically all filters were blacker than any collected in Staten Island; in fact, light filters were attributed to malfunctioning pumps. These observations tend to indicate that heavy particulate loading is of primary importance in New Jersey, but this form of air pollution is a minor consideration in Staten Island. This confirms the findings of other investigators.

INTRODUCTION

Throughout several decades prior to authorization of the present study, the most obvious manifestations of air pollution such as reduced visibility and obnoxious odors, as well as certain of the less easily recognized effects, had been reported in the New York-New Jersey metropolitan area. Countless complaints from the general citizenry and several studies by official agencies all tended to confirm that air pollution--both intrastate and interstate--was a significant problem in this area of dense population and heavy industrial activity. But while the existence of air pollution appeared to have been established, by both subjective and objective means, its extent and intensity had not been adequately investigated.

At the outset of their planning, the Interstate Sanitation Commission recognized the desirability of employing a scientific method to demonstrate the dispersion patterns of pollutants transferred from one state to the other and, insofar as possible, to relate the resulting data to actual interstate air pollution phenomena. In view of the several other facets to be included in the overall study, however, it was believed that such an undertaking would require expenditure of a disproportionately large share of the available appropriation. Therefore, the Commission requested assistance of the Public Health Service, United States Department of Health, Education and Welfare, in planning and conducting an atmospheric transport project to determine the movement of air masses--and, hence, air contaminants--between the two states.

The Public Health Service agreed to participate in the endeavor and, in its role as coordinator of all Federal activities in the field of air pollution control, to negotiate with other Governmental agencies to obtain their assistance. Several planning conferences were held to arrange the technical details of the project and to delineate the respective roles of the various participants prior to consummation of a memorandum of agreement. The type and extent of assistance given by Federal agencies are included in the following sections of the report.

PROJECT PLANS AND METHODS OF OPERATIONS

Tracers

In studying the movement of air masses, it was desirable to introduce into the air a substance which would serve as a tracer. The principle of using tracers to study the flow of liquids and gases was not particularly novel,* but recent developments had made the technique applicable to air pollution investigations. (1) (2) (4) (5).

Ideally, a tracer should be one which does not occur naturally in the air, it should be nontoxic, easily dispersed, stable in the atmosphere, and readily collectable; in addition, it should have a characteristic property which permits positive identification and quantification in minute concentrations. (2) (5)

Several possibilities presented themselves. Biological or radioactive materials, chemicals with specific reactions, and substances with certain physical properties might be employed as tracers. Each has its advantages and its limitations.

A fluorescent zinc cadmium sulfide dust was chosen as the most advantageous for this project. The material, identified as NJZ 2266, batch CEP-8000, lot 002, is a product of U. S. Radium Company of Whippany, New Jersey. The United States Army Chemical Corps Research and Development Command, through its Biological Warfare Laboratories at Fort Detrick, Frederick, Maryland, agreed to furnish an ample supply of the tracer material for use in the study.

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* Natural examples of the tracer method, in its simpler forms, are familiar to everyone: floating leaves on a stream and smoke in the atmosphere, for instance, accurately follow the currents of their supporting media.

Chemical Corps consultants, from the inception to the conclusion of the project, actively participated in all of its aspects. Great reliance was placed on their advice in planning and executing the project and in assessing and evaluating results. They lent considerable amounts of specialized equipment and provided many of the expendable supplies.

The Public Health Service, through its Community Air Pollution Program at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio, agreed to provide a full-time sanitary engineer to serve as Project Officer for the tracer study and to furnish such other support and assistance as might be required.

Objective and Scope

The objective set for the project was: To investigate qualitatively, using an airborne particulate tracer material (zinc cadmium sulfide), the atmospheric transport of pollutants in both directions across the common boundary of the States of New Jersey and New York.

Five separate phases of the project were planned, as follows:

Phase I - Dissemination of the tracer material in New Jersey, with Staten Island as the sampling area.

Phase II - Dissemination of the tracer in Manhattan, New Jersey being the sampling area.

Phase III - Dissemination in Staten Island and sampling in New Jersey.

Phase IV - Dissemination in New Jersey and sampling in Manhattan

Phase V - Dissemination of tracer material at a central site (probably in New York Bay) and peripheral sampling within the study area, in all directions, to investigate the area-coverage of pollution masses existing over the New York-New Jersey area during atmospheric stagnation periods.

It was decided to make a concerted effort to complete the first two phases, since they were the minimum necessary to determine whether there was interstate transfer of air pollutants in both directions. The last three phases depended on the remaining time and budget and in addition, Phase V was considered optional, contingent on the outcome of Phases I through IV. (Owing to various developments--some of which, in retrospect, might have been prevented, but others of which were uncontrollable, only the first two phases could be undertaken before the expiration of the time allotted for the study.)

Meteorology

One of the major factors involved in a study of this sort is meteorology. It is essential that meteorological advice and guidance be utilized in planning, conducting field operations, and analyzing results from atmospheric tracer studies, (5)

United States Weather Bureau meteorologists assigned to the Meteorology Section of the Public Health Service's Community Air Pollution Program assumed the important duties of planning the project from the meteorological viewpoint, forecasting for field tests, operating the project meteorological station, supplying all required weather data, and assisting in the evaluation of test results.

Based on their study of Weather Bureau records for the New York metropolitan area, the meteorologists recommended that best results could be expected if the various phases were scheduled as follows:

> Phases I and IV - November to April (period of highest frequency of westerly component winds).
>
> Phases II and III - May to October (period of highest frequency of easterly component winds).

Phase V - September to November (period of highest frequency of extended atmospheric stagnation).

In a comprehensive study of the interstate movements of air masses, it would have been ideal if tests could have been run under a variety of suitable meteorological conditions, regardless of the time of day or night. However, more practical considerations entered into the planning: Part-time personnel had to be recruited to assist in the field work, and sampling stations were set up on private property. Primarily for these reasons, it was planned to limit testing periods to the hours between sunset and sunrise, preferably between 7:00 p.m. and midnight. It was believed that this schedule would not interfere unduly with the regular activities of the part-time personnel nor greatly inconvenience the persons who authorized the establishment of sampling stations on their properties. Moreover, atmospheric temperature inversions or, at least, neutral stability might reasonably be expected in the evening when the earth cools rapidly due to radiation. Another factor which entered into this decision was the expectation that traffic, industrial operations and other activities might be reduced at night. This would result in a decrease in the amount of particulate matter emitted to the air and, thus, would reduce the possibility of interference with the detection of the fluorescent tracer on the collecting medium.

Accurate weather forecasting was, of course, vital to the success of the tracer project. Fortunately, the New York-New Jersey area has a multiplicity of weather stations, affording considerably better coverage than that of most localities. The full facilities of the Weather Bureau Office at 17 Battery Place in Manhattan were made available for use by the project meteorologist. This office became his base of operations and contact with the field headquarters was by telephone. In addition to the continuous observations made at the Weather Bureau Office, the project meteorologist had at his disposal surface and upper-air charts and the teletyped hourly airways weather reports from seven other weather stations in or near the metropolitan area of New York City. Vertical temperature data, obtained by rawinsonde, were available several times a day from New York International Airport (Idlewild).

Dispersal of Tracer Material

Satisfactory dissemination of the tracer involved the general problem of dispersing a finely divided solid material in the air as single, discrete particles without clumps or agglomerates. (2) (4) (5). Suitable aerosol clouds of the tracer were created by using a disseminator provided by the Army Chemical Corps. This special device, developed by the Department of Chemistry at Stanford University, consisted essentially of a modified Skil-Blower with a 110-volt, one-kilowatt motor; it delivered 5000-5500 liters of free air per minute with a nozzle velocity of about 100 feet per second. (4) (5) A very small mass of the tracer powder produced a great number of individuals particles; as dispersed, about 3×10^{10} particles were rendered airborne for each gram of released material. (5)

Normally, the disseminator was equipped with a precision feeding device, the hooper of which held 80 grams of powder. Amounts of tracer material considerably larger than 80 grams were used for each test in this project. The feeding device was removed from the disseminator, therefore, to avoid the need for weighing additional powder and refilling the hopper during dissemination. Instead, the operator fed the tracer material manually, at a predetermined rate, into the disseminator from pre-weighed 20-gram lots stored in screw-cap test tubes. While this method may not have been so precise as the mechanical feeder, it gave satisfactory results.

The point at which tracer material was dispersed in the air depended almost entirely on the existing wind direction and speed. Since this was relatively short-range study, it was considered inadvisable to establish fixed dissemination stations. Instead, the disseminator was mobile and a series of satisfactory sites on various headings was selected beforehand. Open areas, free from hills, tall trees and structures, and removed from vehicular and pedestrian traffic, were chosen for this purpose. Permission to use the sites was obtained from proper authorities, and the local police at each point were apprised of the activities. Based on meteorological advice, the project officer, via telephone, dispatched the operator to the most favorable dissemination point about one hour before release time. Once instructions were given, the operator could not be contacted to change the amount, time, or place of dissemination. This accounted for several unsuccessful tests; sudden shifts of wind, failure of samplers, and other emergencies which occasionally arose made desirable the maintenance of continuous contact with the operator.

Dissemination equipment and supplies were transported in a sedan-delivery truck. During dispersal of the tracer, the disseminator was operated from the roof of the truck. Power was furnished by a portable, gasoline-griven, 1500-watt, 110 volt A. C. Homelite electric generator which was placed on the ground beside the vehicle.

The ultimate success of a tracer test depended to a great extent on the effectiveness of the dissemination. (4) (5) This important duty was performed by a full-time employee of the Interstate Sanitation Commission. To prevent possible contamination of the testing site, the operator, truck, supply of tracer material, and dissemination equipment remained outside the sampling area. Similarly, personnel engaged in sampling and laboratory operations did not engage in dissemination, handling of the fluorescent powder, or any other activity that could grossly contaminate them with the tracer material.

The density of the tracer material was 4 gm/cc and the mass median diameter of particles was approximately 2 microns. (2) (4) (5) (6) Practically inert and non-hygroscopic, the tracer was not greatly affected by chemical or photochemical action in the atmosphere. As with any airborne particulate, the possibility of settling of the fluorescent particles could not be overlooked. Settling is believed to have been negligible in comparison with the scale of the tests, however, not only because of the small particle size, but also due to particle roughness and vertical mixing in the air. According to Shallenberger and Stecker, "over reasonable distances and periods of time (the particles) travel in a manner analogous to the molecules of the air mass in which they are entrained." (5) Perkins and co-workers reported "no change in the mass median diameter of air-borne NJZ 2266 in four miles of daytime travel at a housetop wind velocity of 7 mph." (4)

Sampling

The fluorescent particles were detectable only with special instrumentation, but collection equipment was comparatively uncomplicated and required only a minimum of attention and maintenance. It was operable by relatively untrained personnel after a brief orientation. This permitted the hiring of part-time field men to collect the samples and resulted in a considerable reduction of the operating cost. Field men, titled route captains, were local residents who were required to provide their own transportation and timepieces. Flashlights, penciles, clipboards, reporting forms, official identification cards, and other necessary supplies were furnished by the Interstate Sanitation Commission.

Each route captain was responsible for operating certain specified samplers, and each had an alternate who was familiar with the route and could perform the duties if the captain was unavailable. (Field personnel were paid at the rate of $10.00 per test plus eight cents per mile, from residence to residence, for use of their automobiles. They were paid a standby fee of $2.00 plus mileage allowance whenever they were alerted, reported for duty, and the test subsequently had to be canceled).

Sampling equipment consisted essentially of a vacuum pump, a flow-control device, collecting medium, a holder for the medium, and the necessary connective tubing.

Gast vacuum pumps, models NF10 and 0210, with 1/4 horsepower electric motors, were supplied by the Army Chemical Corps. These were later supplemented by Gast model 0211 pumps, with 1/6 - horsepower motors, purchased by the Commission. All pumps had virtually the same features and gave similar performance.

The pumps borrowed from the Army were noisy. Consequently, after demonstration of the pumps, several people who earlier had agreed to allow sampling at their homes refused to permit the installations; others after only a few tests had been made, requested that the samplers be removed. For awhile, this threatened disruption of the sampling network gave rise to serious doubts concerning the eventual success of the entire project. The problem was solved by installation of the pumps of mufflers purchased from the Gast Manufacturing Company of Benton Harbor, Michigan, the manufacturer of the pumps. Noise was reduced to unobjectionable levels by the mufflers, and such complaints were completely eliminated.

Type AA, 47-mm Millipore Filters served as the collecting medium. These porous cellulose membranes, manufactured by Millipore Filter Corporation of Watertown, Massachusetts, trap submicron particles on the upper filtering surface with a superior degree of efficiency. This greatly facilitated the detection of tracer particles.

Filters were held in specially designed filter holders. The top portion of the filter holder consisted of a short, thick-wall metal cylinder, the bottom edge of which was molded for insertion of a tight-fitting neoprene O-ring. The outside surface of this piece, near the bottom, contained a circumferential groove which engaged three spring clips on the base of the holder and secured the two parts together firmly. A stainless steel wire-mesh screen built into the base of the holder supported the filter. When the two parts were assembled, the O-ring served as an air seal around the periphery of the filter. The bottom of the base reduced to a short nipple which fit conveniently, but snugly, into the rubber tubing leading to the vacuum pump.

Thick-wall, white rubber tubing of 1/4 inch bore was used for the vacuum lines. To prevent undue resistance to flow, the length of tubing was limited to six feet in all cases. When not in use, tubing was plugged with wooden dowels or corks to prevent the entrance of insects, dust, and other foreign matter which might have clogged the tubing or restricted air flow.

Air flow was controlled, at approximately 12.5 liters per minute, by cutting the rubber tubing about one foot from the filter end and inserting precision-bore glass capillary tubes (critical orifices). To prevent the possibility of air leakage through the hose splice, rubber tape was placed around the joint.

Filter holders were, in all cases, supported in a horizontal position and were oriented upwind, i.e. facing in the direction of the dissemination points.

Filters, filter holders, and critical orifices were furnished by the Army Chemical Corps, Fort Detrick, Maryland.

Idealized sampling arrays, based largely on topographical and meteorological factors, were laid out during the advance planning. These had to be modified somewhat, in each phase, to conform with practicalities. Particularly pertinent in these modifications were the availability of transportation arteries for efficient movement of field men and the locations of volunteers who would permit the installation of sampling equipment on their properties.

Clear areas, free from trees, adjacent upwind structures and other obstructions were sought as sampling sites at private homes, public buildings, industrial plants, and business houses.

Permission of property owners was obtained by having them sign form letters from the Interstate Sanitation Commission (see Appendix for examples). In order to reduce expenses, it was originally intended that volunteers would be asked to contribute electric power for operation of the samplers. It was found while establishing the network in Phase I that practically all of the property owners were willing to do this; a few, however, insisted that they be reimbursed. Subsequently payment of a nominal fee of 25 cents per test was authorized by the Commission. Letters to that effect were sent to all volunteers except public agencies, some private institutions, and a few industrial concerns who agreed to furnish, without charge, power for operation of the samplers. (A sample letter is included in the Appendix).

In Phase II, payment was authorized on the form letters signed by the property owners (see Appendix).

Locks, dogs, admittance to the property, access to the sampler at all times, readily available electrical power whenever needed, and other matters had to be considered in each case. The property owners were apprised of the hours of operation and the approximate duration of the testing program. Such advance planning and public relations, while time consuming, were invaluable in assuring smooth operation during subsequent field tests.

Preparing Sampling Media for Field Use

Preparation of the sampling media for field use required considerable care by trained personnel if samples were to be satisfactory.

Filter holders were disassembled, scrubbed with brushes in detergent and warm water, and rinsed in running water. To hasten drying, the holders were then immersed in very hot water, if available, or in ethyl alcohol. The separate components of the filter holders were placed on paper towels and allowed to air dry.

Blunt-edge forceps were used to place filters (filtering surface upward, according to the manufacturer's designation) on the stainless-steel screen in the base of the filter holder. The top section of the holder was then carefully and evenly forced in place between the spring clips. This was the most critical step in the procedure, for the filters were extremely fragile and easily ruptured; uneven placement of the top section of the holder would slide the filter to one side, causing wrinkles in the filtering surface or incomplete engagement of the O-ring around the periphery of the membrane.

A short piece of adhesive Labelon marking tape was stuck to each filter holder. After exposing a filter, the route captain identified the sample by writing the station number on this tape. The open ends of the filter holders were sealed with 2-inch wide masking tape immediately after preparation. This tape was removed by the field men just prior to sample collection and it was replaced as soon as sampling was terminated. In this manner, entrance of extraneous matter was prevented before and after the test.

For the convenience of field personnel, carrying ranks were fashioned from 16-1/2 inch pieces of smooth 2" x 4" lumber. Each of these held 10 assembled filter holders.

Assessment of Samples

Immediately after each test, the exposed filters were carefully removed from the filter holders and fastened with rubber cement to 2" x 3" glass slides. The test designation, in Roman numerals, was written on each slide with wax crayon. To reduce the possibility of human error during transcription of data, the marking tapes containing station numbers were transferred directly from the filter holders to the corresponding slides.

When the mounted filters were illuminated from above by two General Electric 100-watt B-H4 ultraviolet lamps, one on either side of a microscope and at as high an angle as possible, the tracer material gave off an intense visible yellow fluorescence. At 100X magnification, it was possible to identify with relative ease particles as small as 0.5 micron in diameter. (2) (4).

Following each test, the filters were scanned microscopically by the Project Officer and his assistant, to evaluate the success of the test. Although counts were not made during the scanning, information gained by the procedure aided in planning future tests. Dissemination amounts or locations could be revised, malfunctioning samplers could sometimes be spotted, and faulty techniques of various sorts could be detected on the basis of this cursory inspection of the filters.

Final assessment of the filters was performed in accordance with routine procedures, (2) (3) by the Materiel Testing Branch, Chemical Corps Research and Development Command, Dugway Proving Ground, Dugway, Utah, under a contract negotiated and financed by the Public Health Service. Samples were packed in 25-slide capacity wooden boxes, carefully wrapped, and mailed to Dugway; written reports were sent to the Project Officer by return mail.

CONTAMINATION, BACKGROUND AND CONTROL SAMPLES

In the early planning stages, several months before organized field testing was undertaken in Phase I, background samples were collected at various times of the day and night at several locations in Staten Island. The primary reasons for collecting the samples were:

1. Since the manufacturer of the fluorescent powder was located in New Jersey, there was the possibility that some NJZ 2266 escaped to the atmosphere with plant emissions and was present in the atmosphere of the metropolitan area. It was advisable to determine this in advance so that plans could be altered, if necessary. (Zinc cadmium sulfide tracer material is not normally found in the air and, owing to its intense fluorescence, it is unlikely that other airborne particulates could be mistaken for it.)

2. In a metropolitan area such as New York, it was highly probable that the concentration of usual airborne particulates was millions of times as great as the amount of tracer material put into the air during a test. This could cause obscuration of the fluorescent particles on the collecting medium. Therefore, it was desirable to obtain an estimate of the airborne particulate loading which might be expected under a variety of

conditions. Such information would be useful in predicting the length of time that samplers could be operated during testing periods without interfering with the detection of fluorescence.

From January 23rd to 25th, 1957, eight samples of from 2 to 15 hours' duration were collected. Another series of 26 samples was collected from April 15th to May 16th, 1957; the sampling periods varied from 10 minutes to 11 hours.

These samples were examined by Chemical Corps consultants at Fort Detrick. They found that, except under certain extreme conditions, the samplers could be operated up to 5 hours, as planned, or longer, with no foreseeable significant obscuration of fluorescence.

It was reported that four of the April-May samples were positive for fluorescent particles of the type to be used in the project. Although this caused a great deal of concern for awhile, the presence of tracer material in the air was subsequently ruled out and the trouble was traced to contamination during filter preparation.

Preventing contamination was of utmost importance if maximum sensitivity was to be obtained from the tracer study. (4) This was learned by an unhappy, but memorable, experience early in the project. It was discovered after the first test that filters had been so seriously contaminated before exposure that the test results were unreliable. Filters which had been prepared at the field headquarters were examined individually through the microscope and found to contain as many as 32 fluorescent particles. To determine the degree of contamination present in the room, a 10-minute sample was collected in the headquarters by the conventional field method while the floor was swept to stir up settled dust; thousands of fluorescent particles were found on the filter.

An attempt was made to rationalize the reason for, and source of, the contamination. It was recalled that the sampling and disseminating equipment had been recieved in a single shipment, they had been stored together and unpacked in the same room. Moreover, the supply of millipore filters had been packed in the shipping box with the disseminator, which had been used on a previous study and had been inadequately cleaned, if at all, before shipment. Considering these factors, it was not then difficult to appreciate the full significance of the advice given by Perkins and associates; (4) "If the maximum sensitivity is desired, extreme precautions must be taken, such as placing storage and analytical activities in separate buildings. . ."

A new supply of millipore filters was furnished by the Chemical Corps and filter-preparation work was subsequently transferred to a different area. Control samples were collected in the room periodically to detect any contamination that might have been present. In the new quarters, with extreme care and improved techniques, it was relatively easy to prevent recurrence of significant contamination.

Control samples were routinely collected at four to six scattered stations in the sampling network during the two to four hour period immediately preceeding each test. Thus, a constant check was maintained for background fluorescent particles.

PUBLIC INFORMATION

An attempt was made to keep the public informed, through official press releases from the Interstate Sanitation Commission, of the progress of the atmospheric tracer project. In doing so however, in accordance with an administrative decision of the Commission, information concerning the specific type of test being conducted was not revealed to the press, to sampling-site volunteers, or even to part-time personnel. The intent was to prevent undue excitement of the public, who might have confused the fluorescent tracer with radioactivity or other potentially harmful substances. It had the added advantage of greatly reducing the possibility of intentional biasing of results.

DEMONSTRATION PROJECT GRANT

The tracer technique used in this atmospheric transport project, while not entirely new, had never before been employed in an extensive community air pollution study of this sort. It was desirable that additional information be obtained to evaluate the potential applicability of this approach to air pollution investigations. Therefore, in addition to the direct services, equipment, and supplies furnished by

Government agencies to assist in the tracer project, the Interstate Sanitation Commission was awarded a demonstration project grant in the amount of $20,450. by the Public Health Service.

PHASE I

Scheduling

Actual or potential air pollution--from the interstate standpoint--was the prime consideration in assigning priorities to the several phases of the atmospheric transport project. By this criterion, the New Jersey-to-Staten Island phase could hardly be denied top priority. The unrelenting expressions of discontent by Staten Island residents and confirmatory conclusions of official agencies,* as well as geographical and sociological factors, practically dictated this position. From the outset, planning was concentrated on getting Phase I underway as quickly as possible.

This phase involved the dissemination of fluorescent tracer material in New Jersey and sampling in Staten Island. According to climatological prediction, wind conditions for this phase would have been most favorable between November and April. Preliminary planning was begun in ample time to meet the recommended schedule, but a series of circumstances and uncertainties (including most importantly, expiration of the authorizing State legislation, which was subsequently extended) prevented the commencement of field testing before the latter part of May, 1957.

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* Megonnell, W.H., New York-New Jersey Interstate Air Pollution Study, Historical Review, July 1957, mimeographed (available from the Interstate Sanitation Commission).

Thus, operations in Phase I began after the recommended period had already passed. Unfortunately this forced the scheduling of test runs during a season of the year in which there was a high frequency of non-operational weather conditions. Winds were predominately unfavorable and, on several occasions, waiting periods of 15 days were encountered between satisfactory testing conditions. It was the original intent to conduct tests chiefly during atmospheric stagnations, low-level inversions, and other periods of likely air pollution; this ideal had to be abandoned, however, and suitable wind direction became the dominant test criterion.

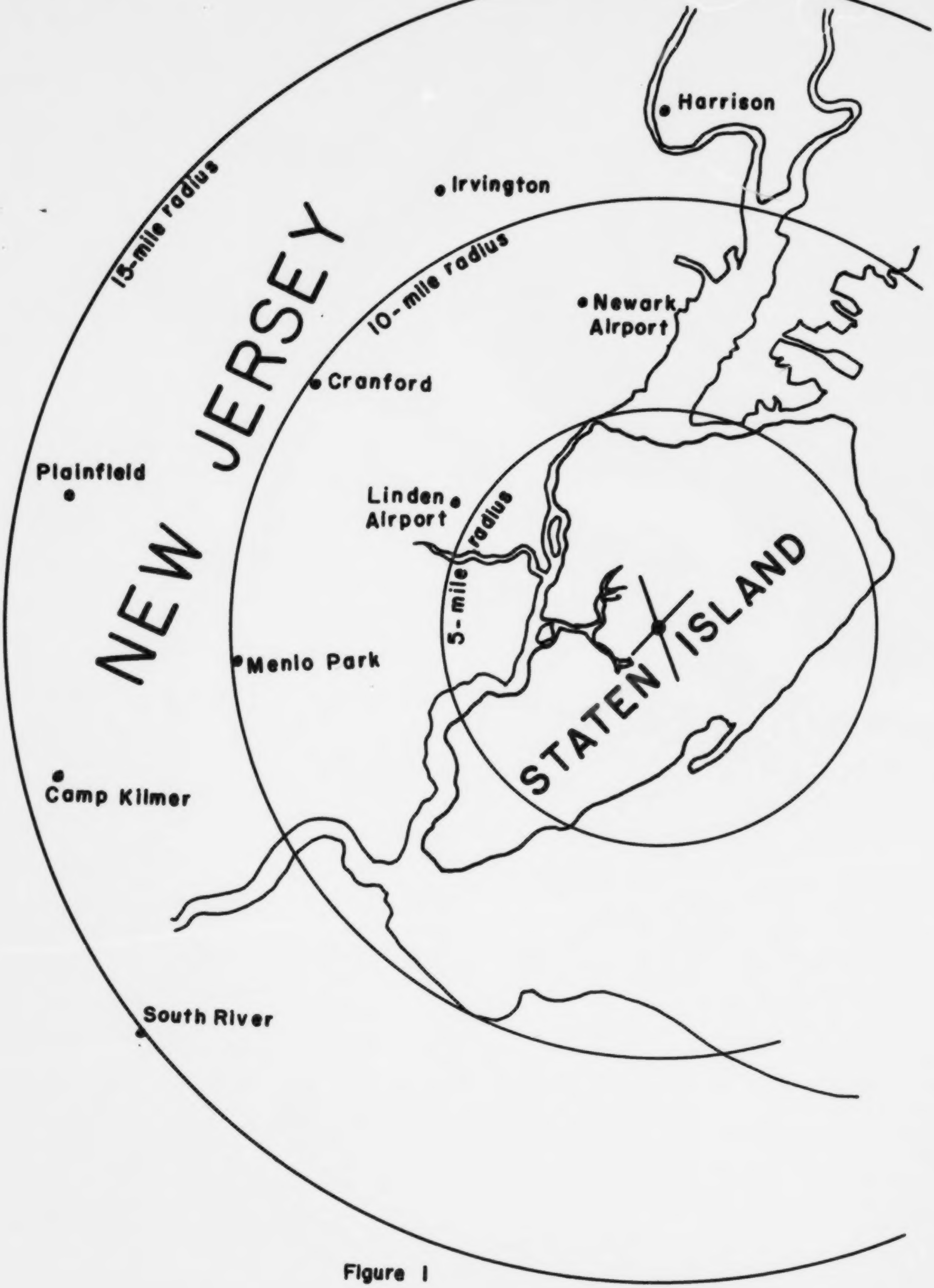
Dissemination Points

In the selection of dissemination points in New Jersey, no effort was made to pinpoint any specific locality or industrial complex as a primary source of interstate air pollution. On the contrary, every attempt was made to avoid such implication. Thus, the points selected for dissemination of the tracer did not necessarily bear a relationship to actual or potential air pollution sources. The points were at least five miles from the center of Staten Island (Figure 1), whereas the most important sources of interstate air pollution probably were much closer--perhaps along the Kill van Kull and the Arthur Kill, the narrow tidal estuaries separating Staten Island from New Jersey.

The reasoning behind this selection of dissemination points is believed to have been sound. In this short-range study, it was impossible to investigate the contribution of all, or even most, of the known or suspected sources to the interstate air pollution problem. To choose only certain ones as sites for dispersal of the tracer might have resulted in unfair implication of those sources as the major causes of interstate air pollution.

The tracer material was released from the truck roof at only one location during a test, giving virtually a ground-level point-source dispersal. This type release permitted the air-borne tracer material to spread upward and laterally before it reached the States' boundary. Therefore, although perhaps of only academic interest, the tracer resembled somewhat a line source at various heights

42-B



Harrison
Irvington
15-mile radius
NEW JERSEY
10-mile radius
Newark Airport
Cranford
Plainfield
Linden Airport
5-mile radius
STATEN ISLAND
Menlo Park
Camp Kilmer
South River

Figure 1

by the time it reached the Kills; this would appear to simulate somewhat the actual conditions which existed at this boundary with its multitude of high-and-low-level emissions.

Sampling Network

A brief description of the area may be of value in explaining the reasoning behind the layout of the sampling system.

Staten Island is a paradoxical portion of New York City. It is uncrowded; much of it is untenanted, even desolate. The island is nearly 14 miles long and about 7 1/2 miles across at its widest point. Over half of its 36,600 acres are undeveloped, consisting of salt marshes, meadows, uncultivated fields and woods. More than 4,000 acres are reserved for parks, playgrounds and beaches. A sizeable proportion is devoted to farming. While Staten Island could probably best be described as suburban and maritime, parts of it are definitely rural in character.

The south shore and the northwest areas of Staten Island are low and relatively flat. The southwest portion consists of rolling hills which rise to more than 100 feet. Beginning at the northeast corner and continuing southwesterly for about one-half the length of the Island is a series of ribbed hills with elevations to 400 feet.

On the basis of these topographical features, and records which revealed that the annual prevailing winds were northwesterly, it was decided to locate samplers at approximately one-mile intervals on each of three concentric arcs spaced about 2 miles apart and with a theoretical focus about 5 miles northwest of Staten Island in New Jersey. This distribution, it was felt, was the minimum necessary to provide adequate coverage of the Island for statistical evaluation of results. It might, at the same time, furnish valuable information on windflow effects attributable to geographical and topographical influences; one arc was on the windward side of the ridge, another on the leeward side, and the center arc followed roughly the ridge line. This idealized sampling pattern is depicted in Figure 2.

Recruitment of sampling-site volunteers in this phase was relatively easy. The Staten Island newspaper publicized and actively supported the project, and there was general local interest and concern in the air pollution problem. But the most important factor in this regard was the cooperative effort of the Staten Island Air Pollution Control Association.

At a special meeting of the organization's Executive Committee, the general outline of field

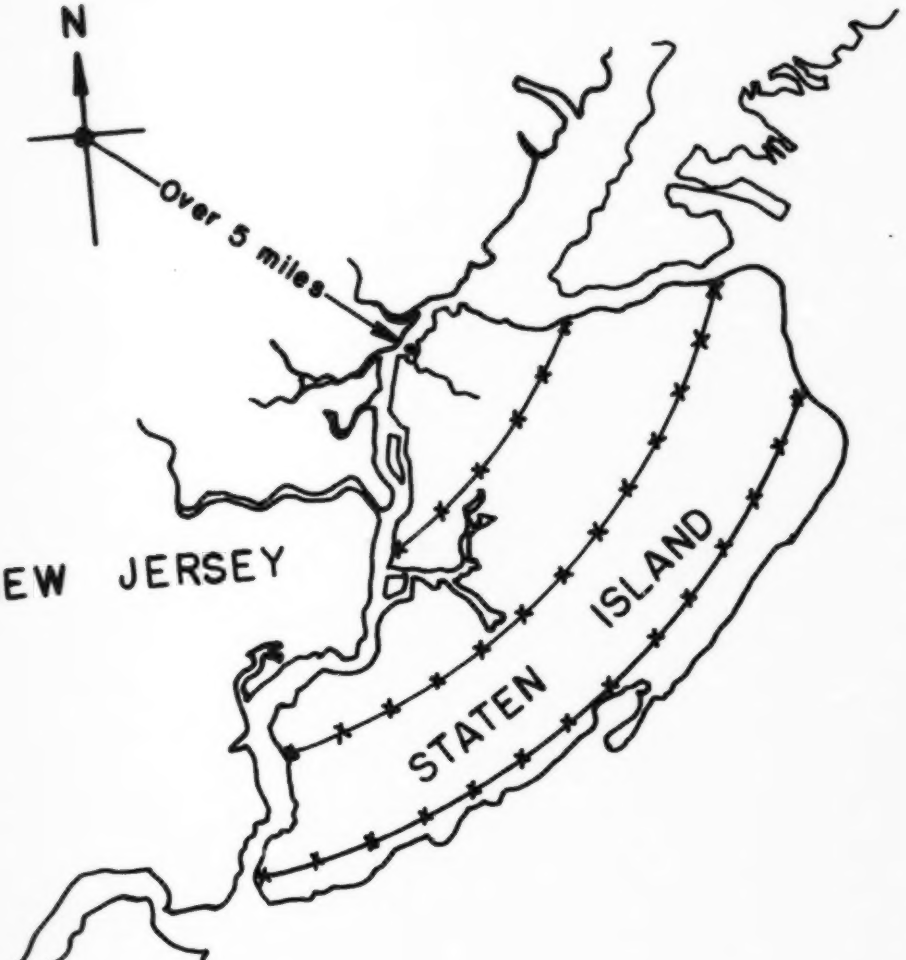


Figure 2

operations was presented by the Project Officer. A map of the proposed sampling network, modified to conform with practicalities, was given to the Committee and their assistance was requested in locating volunteers.

The Association aided immeasurably by locating cooperative property owners at practically all of the desired sites. Although a few of the locations were found to be unsuitable for various reasons, it was comparatively simple to enlist alternates. The 35 sampling stations finally set up followed reasonably well the originally proposed pattern. (Figure 3).

One industrial concern insisted that the Commission assume liability, in writing, for any damage resulting from installation or operation of the sampler. A special insurance policy was purchased to cover that installation.

Of Staten Island's more than 200,000 inhabitants, only about 12 per cent are apartment dwellers; almost half of the families own their own homes. In view of this and the extensive farm and park areas, it was deemed desirable to limit sampling to the lower few feet of the atmosphere rather than to sample on rooftops and at other heights. Filter holders generally were supported on wooden stakes and all samplers were located about 5 feet above the ground. A detailed

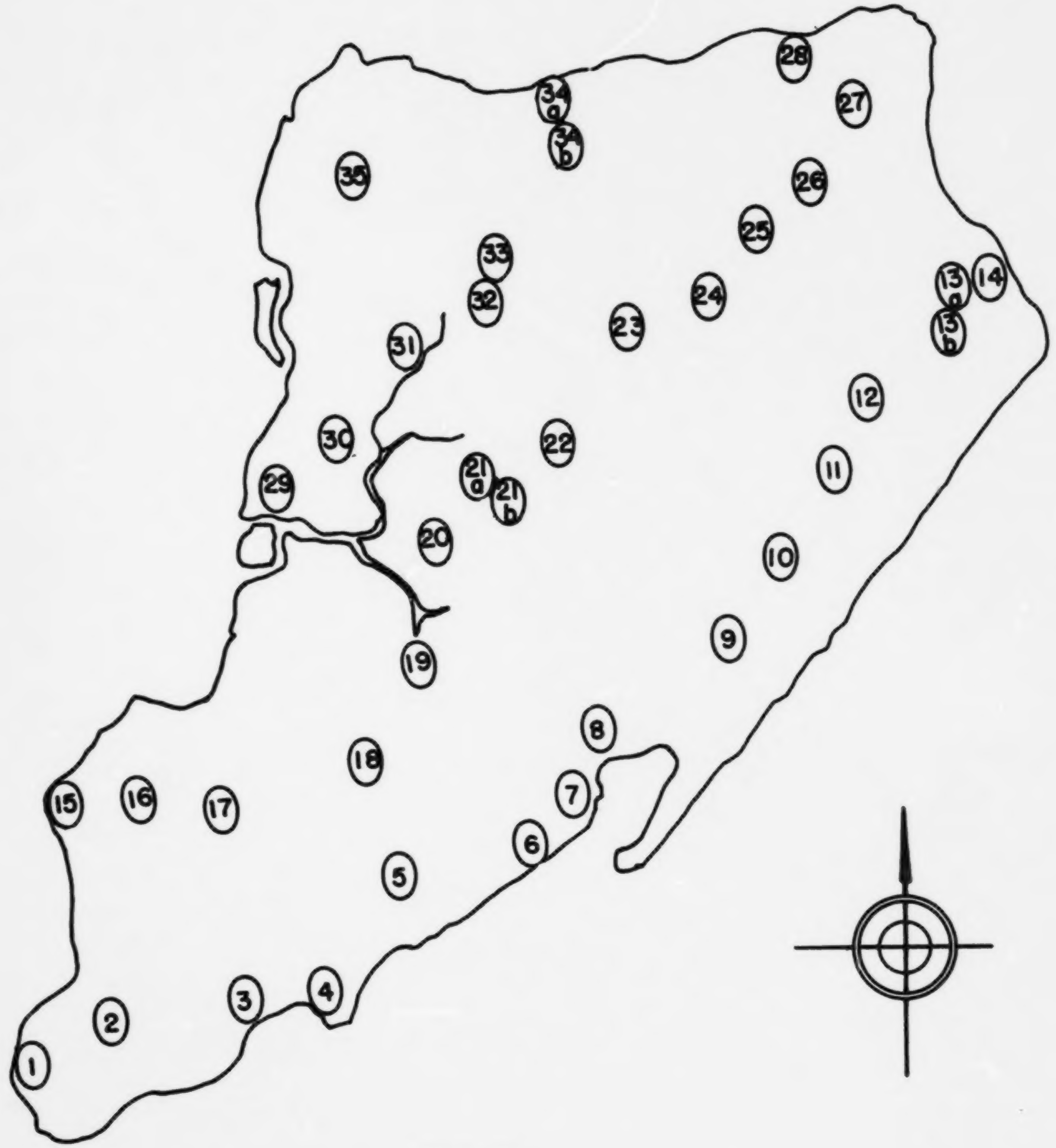

1
2
3
4
5
6
7
8
9
10
11
12
13 a
13 b
14
15
16
17
18
19
20
21 a
21 b
22
23
24
25
26
27
28
29
30
31
32
33
34 a
34 b
35

Figure 3

list and description of sampling stations is included in Table 2 (pages 68-71).

Project Meteorological Station

The Public Health Service supplied a portable 30-foot tower, wind-speed and wind-direction instruments and recorders, a hygrothermograph, wet-and dry-bulb thermometers, maximum and minimum thermometers, and the necessary auxiliary instrumentation and housing to collect meteorological data within the study area.

A satisfactory site for the project meteorological station was found at the Staten Island airport, near the center of the sampling area. The surrounding ground was flat and completely unobstructed for several hundred yards on all sides, and the tower could be so located that it would not be a hazard to aerial navigation.

During the first few field tests, pending completion of arrangements for use of the airport location, a temporary meteorological station was set up and operated on property of the President of the Staten Island Air Pollution Control Association.

Permission to use the airport site entailed considerable time and negotiation between the attorneys for the airport owners and the Commission. An agreement, granting the Commission use of the site free of charge, carried certain stipulations which complicated the establishment of the meteorological station:

1. The Commission was responsible for any personal injury or property damage which might have resulted from the installation. Special liability insurance was purchased to cover this.

2. Any required permits were to be obtained by the Commission. Because of the location on airport property, there was disagreement concerning whether construction approval was to be given by the New York City Department of Buildings or the Department of Marine and Aviation. (The latter also implied that approval by the Civil Aeronautics Authority would be required.)

After search and inquiry, the Commission's attorney gave his opinion that the meteorological station would not come under the Department of Marine and Aviation, if it were situated within 100 feet of Richmond Avenue. Although there was not unanimity on this opinion, application was made to the Department of Buildings. After several conferences, the drawing and submittal of plans, and a structural analysis, they granted a temporary permit for the installation.

Subsequently, it was necessary to apply for extension of the permit. A change of personnel had taken place in the local Department of Buildings office. The new Borough Superintendent advised that, while his Department had no objection to maintenance of the structure, the airport was under jurisdiction of the Department of Marine and Aviation. Thus, the station was erected and maintained, through no fault of the Interstate Sanitation Commission or the other agencies involved in the project, under a permit of questionable validity. Jurisdiction was never satisfactorily clarified.

3. The structure was to be fenced and, upon termination of use, the ground was to be returned to the condition existing before installation of the meteorological station. It was thought that some of the fencing investment might be regained from the salvage value of the materials. Fence companies that were contacted, however, would not agree to remove the fence, except for an additional fee. The most favorable arrangement found by the Commission was to make an agreement with an individual whereby he would retain the fence and appurtenances in exchange for his labor in removing them and in restoring the premises to a satisfactory condition.

Only high- voltage power lines were located along Richmond Avenue in the vicinity of the airport, since that portion of Staten Island was relatively uninhabited. Obtaining alternating-current power for operation of the meteorological instruments would have required either a transformer or the setting of poles and running of several hundred feet of wire from the nearest 110-volt source. Either alternative was costly, so it was decided to use battery power. This was inconvenient, due to the increased attention required. Also, procurement of the special batteries necessitated advance orders; an occasion, delivery was delayed and, consequently, weather records were interrupted.

Unfortunately, the data collected by these instruments could not be used as an aid in forecasting since there was only one meteorologist on duty at a time and he was most advantageously located at the Manhattan office of the Weather Bureau. Information gathered at the project meteorological station was valuable, however, in modifying subsequent field tests, in supporting test findings, and in explaining some of the results.

Field Headquarters

Field headquarters were established in space provided by the United States Public Health Service Hospital at Stapleton, Staten Island, in the basement of the Internes Quarters. One room was reserved exclusively to prepare filters for field use; another was used to store equipment and supplies, to brief field personnel, to direct field operations, and to conduct administrative duties connected with the project. After each test, the samples were mounted on slides and scanned microscopically in the hospital's laboratory.

Sampling Operations

With the assistance of the Staten Island Air Pollution Control Association, conscientious and dependable part-time personnel were obtained to serve as route captains and alternates.

Based on meteorological advice, the Project Officer usually notified route captains by telephone several hours in advance of an impending test. Control samples were set out at random locations in the sampling network by the Project Officer and his assistant; the route captains, as part of their regular duties, picked up the control samples and replaced them with clean filters immediately prior to the test.

Each route captain was responsible for seven stations, and it was found through experience that filters could be set out within one hour or less. Generally, field men were dispatched from headquarters at 7:00 p.m. and dissemination was begun at 8:00 p.m.*

Mean wind speed during the test was used to compute the times that samplers should be shut off. The straight-line distance from the dissemination point to the farthest downwind station in each sampling route was scaled on a map. Based on the mean wind speed, the theoretical time of flight to that station was then computed. To account for a possible lag of the fluorescent particles behind the recorded mean wind speed, one hour was arbitrarily added to each of the computed flight times.* On this basis, each route captain was informed of the time after which he was permitted to pick up his respective samples.

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* In Phase I all times given are Eastern Daylight Saving time

Test Results:

Results of each test are plotted on individual maps (Figures 4 - 17) which show:

1. Dissemination data (place, time, amount of fluorescent material, and rate of emission).

2. The range of reported surface and higher-level wind directions, and the corresponding mean wind speeds, based on all observations during the test.

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* Comparison of data from the project meteorological site with that from other weather stations in the New York-New Jersey area revealed that wind speeds recorded in Staten Island were generally only 1/3 to 1/2 as great as those reported by the other observers. This contrast was believed to be due primarily to the differences in elevation of the various wind instruments. As an additional factor of safety, therefore, mean wind speed reported at the Weather Bureau office was halved before computing shut-off times.

(Data from the weather stations at Idlewild, La Guardia, Newark, Teterboro, and Staten Island airports were included in the surface-wind observations, upper-air winds were those reported at the Weather Bureau Office in Manhattan.)

3. Direction and mean speed of the predominate surface and higher-level winds during the test. The percentage of the observed winds from that direction is also given.

4. Observed sky condition during the test (clear, scattered clouds, broken clouds, or overcast.)

5. The number of fluorescent particles collected at each sampling station. (Where no value is given, the station was inoperative or the sample was invalid for some reason.)

6. Smoothed iso-lines to indicate orders of magnitude of tracer recovery. The general dispersal and flight patterns of the fluorescent tracer material may be determined from the iso-lines.

Following is a brief narrative history of each test made in Phase I.

Run No.I - May 28, 1957. Neutral stability. Experimental release of 240 grams of tracer material. Filters were so badly contaminated during preparation that results were unreliable and could not be analyzed. Test was considered unsuccessful, but it was of value in the orientation and training of personnel. (Figure 4).

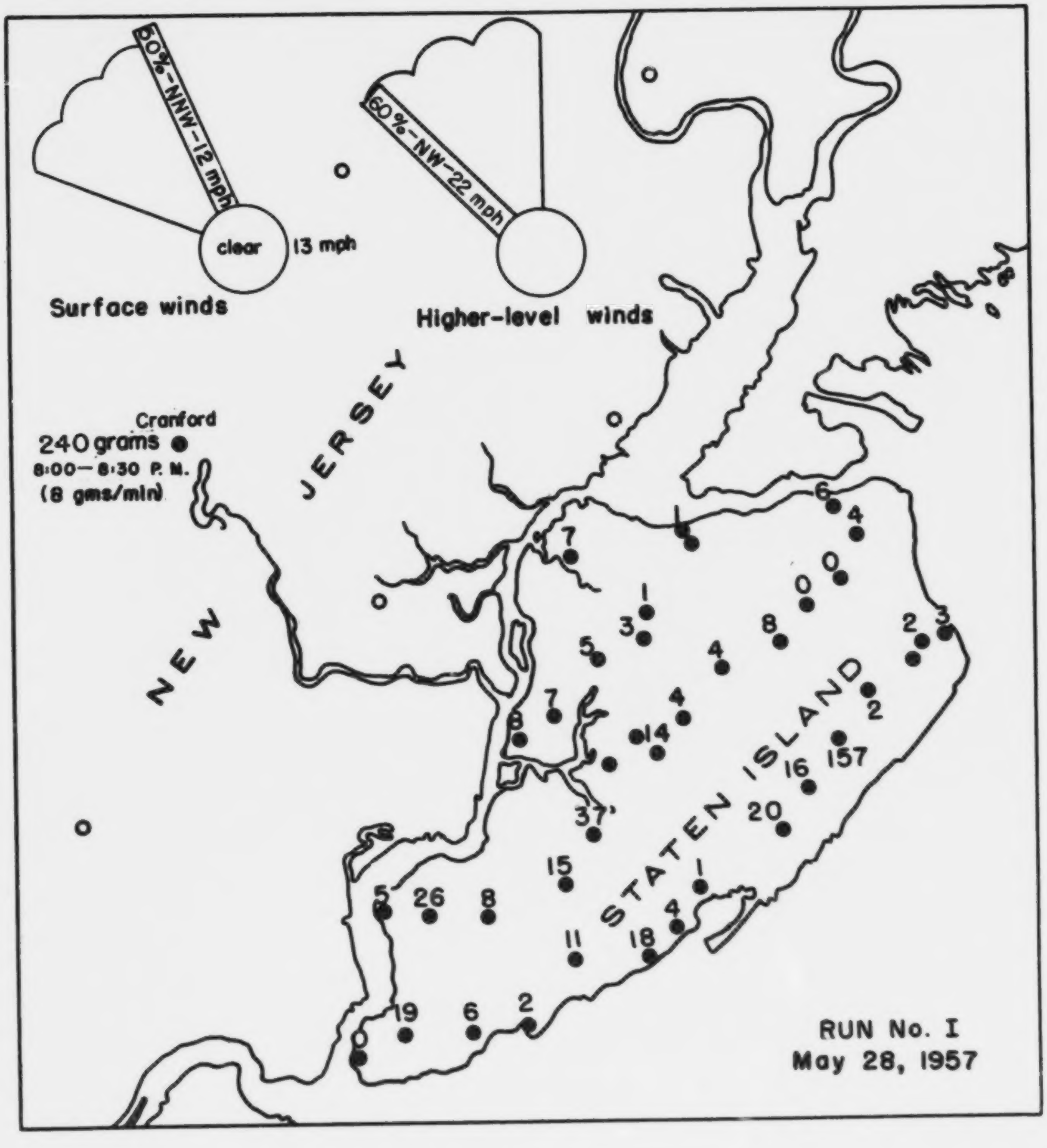

60%-NNW-12 mph
clear
13 mph
Surface winds
60%-NW-22 mph
Higher-level winds
Cranford
240 grams
8:00—8:30 P. M.
(8 gms/min)
NEW JERSEY
STATEN ISLAND
6
4
7
0
0
1
3
8
2
3
5
4
7
4
2
8
14
157
16
37
20
15
1
5
26
8
4
11
18
19
6
2
RUN No. I
May 28, 1957

Figure 4

Run No.II - June 12, 1957. Unstable from surface to 200 feet, neutral stability above 200 feet. Same amount of tracer, 240 grams, released, because of light recovery, it was decided to double the amount for subsequent tests. Results were more reliable than those of the first test, but considerable contamination trouble remained. Test considered unsuccessful (Figure 5).

Run No. III - June 17, 1957. Wind shifted unpredictably from N to S, due to sea breeze effect, midway in the dissemination period. All filters negative; test unsuccessful.

Run No. IV - June 19, 1957. Near neutral stability. No significant contamination. First test to give reliable results. Dispersal pattern of tracer could be followed from west to east across Staten Island in fairly widespread, clearly defined path. (Figure 6).

Run No. V - June 20, 1957. Neutral stability, subsidence inversion of 8°F from 7200 to 8000 feet. Some contamination, particularly at stations 13a and 26, but NW to SE path of tracer could be determined. Note the unusually high concentration of fluorescent particles at station 30 in the nearest upwind sampling arc, the low concentration along the central sampling route, and the intermediate count at station 9 in the farthest

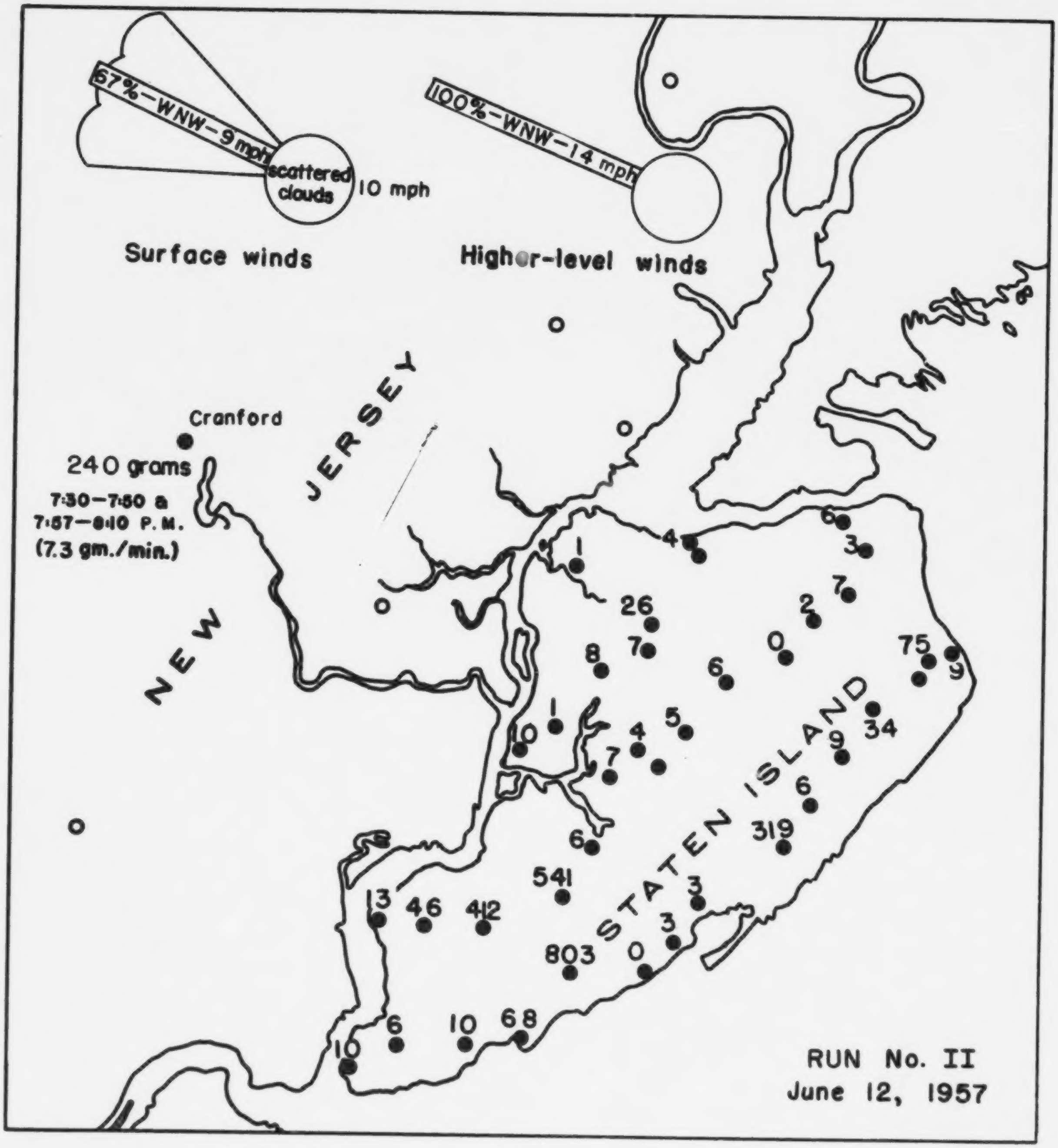

67%-WNW-9 mph
scattered clouds
10 mph
Surface winds
100%-WNW-14 mph
Higher-level winds
Cranford
240 grams
7:30-7:50 &
7:57-8:10 P.M.
(7.3 gm./min.)
NEW JERSEY
STATEN ISLAND
1
4
6
3
26
2
7
8
7
6
0
75
9
1
5
10
4
7
9
34
6
6
319
541
13
46
412
3
3
803
0
10
6
10
68
RUN No. II
June 12, 1957

Figure 5

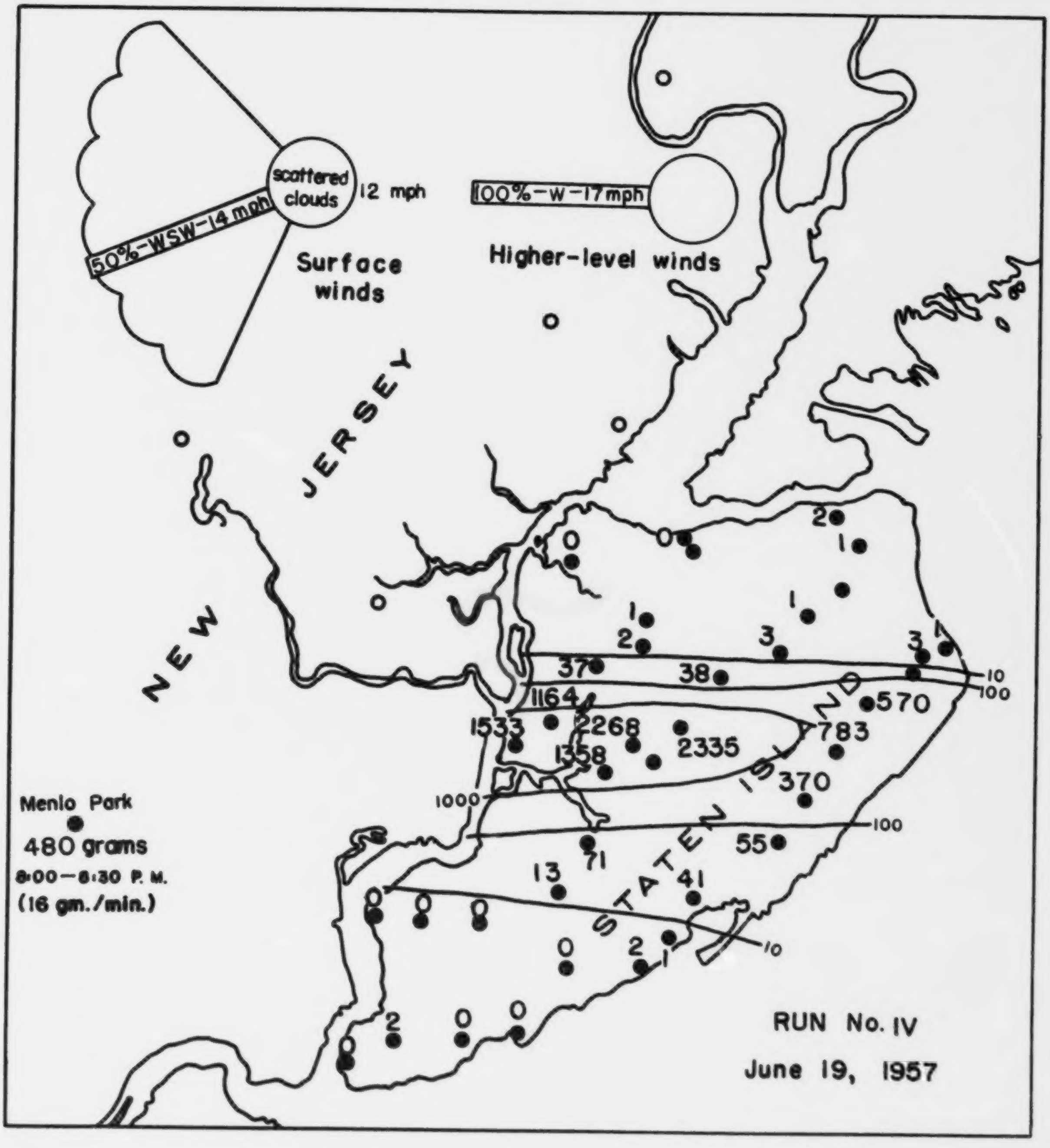

scattered clouds
12 mph
50%-WSW-14 mph
Surface winds
100%-W-17mph
Higher-level winds
NEW JERSEY
STATEN ISLAND
Menlo Park
480 grams
8:00-8:30 P.M.
(16 gm./min.)
RUN No. IV
June 19, 1957
0
2
1
1
1
2
3
3
1
37
38
10
100
1164
570
1533
2268
2335
783
1358
370
1000
100
55
71
13
41
0
0
0
0
2
1
10
2
0
0
0

Figure 6

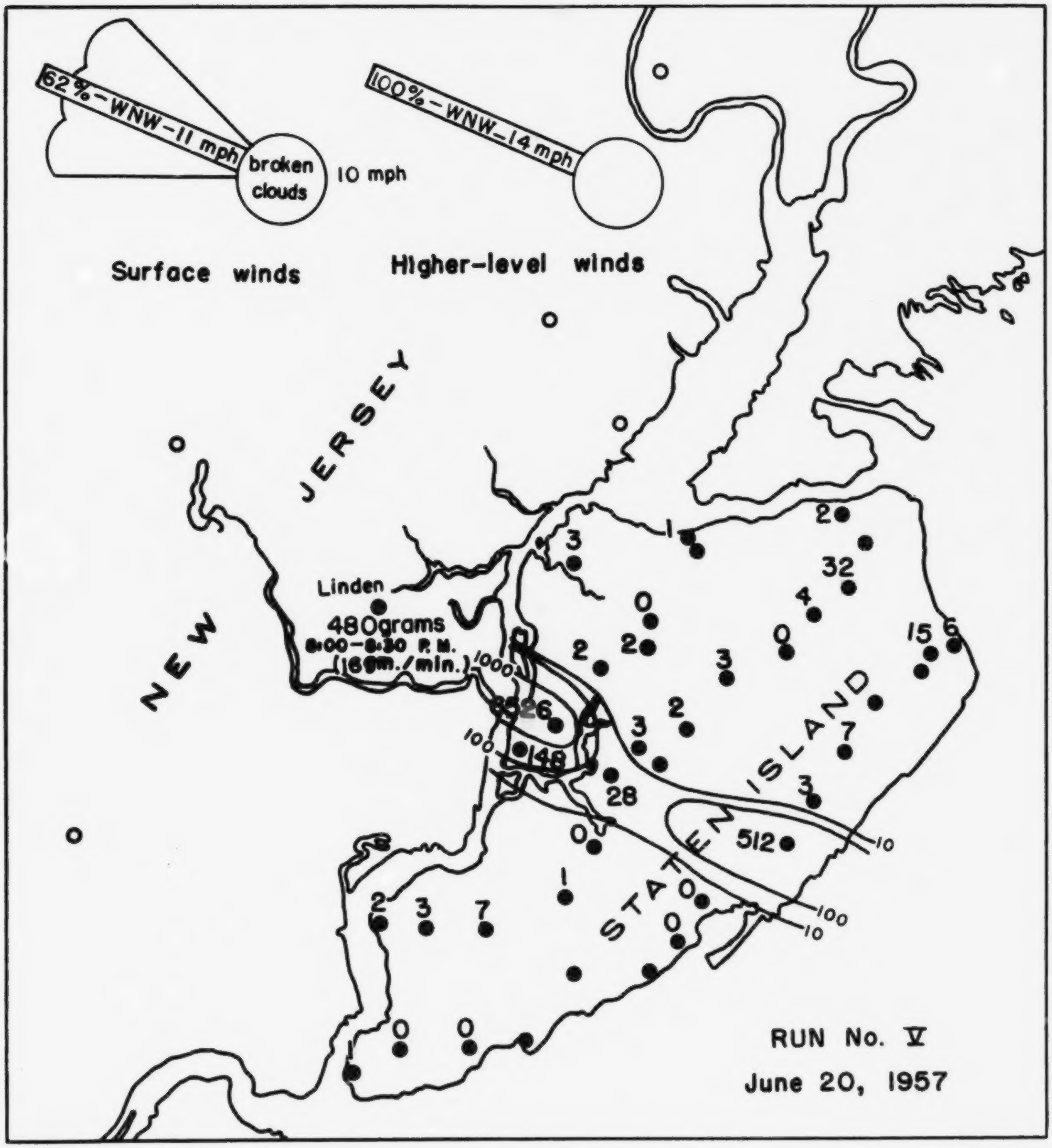
downwind route. This may indicate looping in the atmosphere or uplift of wind near the center of Staten Island due to the topography. Note the definite flight path with little lateral spreading. (Figure 7).

Run No VI - July 1, 1957. Neutral stability; isothermal layer based at 8400 feet due to subsidence. No significant contamination. Tracer missed upwind sampling route entirely, very high count obtained at station 19 on the central arc; moderately high concentration at station 7 of the downwind route. Dispersal pattern may be related to geographical and topographical influences, since heaviest tracer recovery was in the low areas of Staten Island. (Figure 8)

Run No.VII - July 2, 1957. Neutral stability, subsidence inversion based at 8300 feet. Very high concentration of fluorescent particles recovered at station 17. The flight pattern, across the southwestern portion of Staten Island, was very clearly defined with little lateral spreading (Figure 9).

Run No.VIII - July 9, 1957. Shift of wind from eastward to westward was forecast. Filters were set out, but the test was cancelled before the tracer was disseminated. (The predicted wind shift occurred about two hours later)

Run No.IX - July 10, 1957. Unstable from surface to 300 feet, neutral stability above 300 feet, subsidence inversion based at 6600 feet.



RUN No. V

June 20, 1957

Figure 7

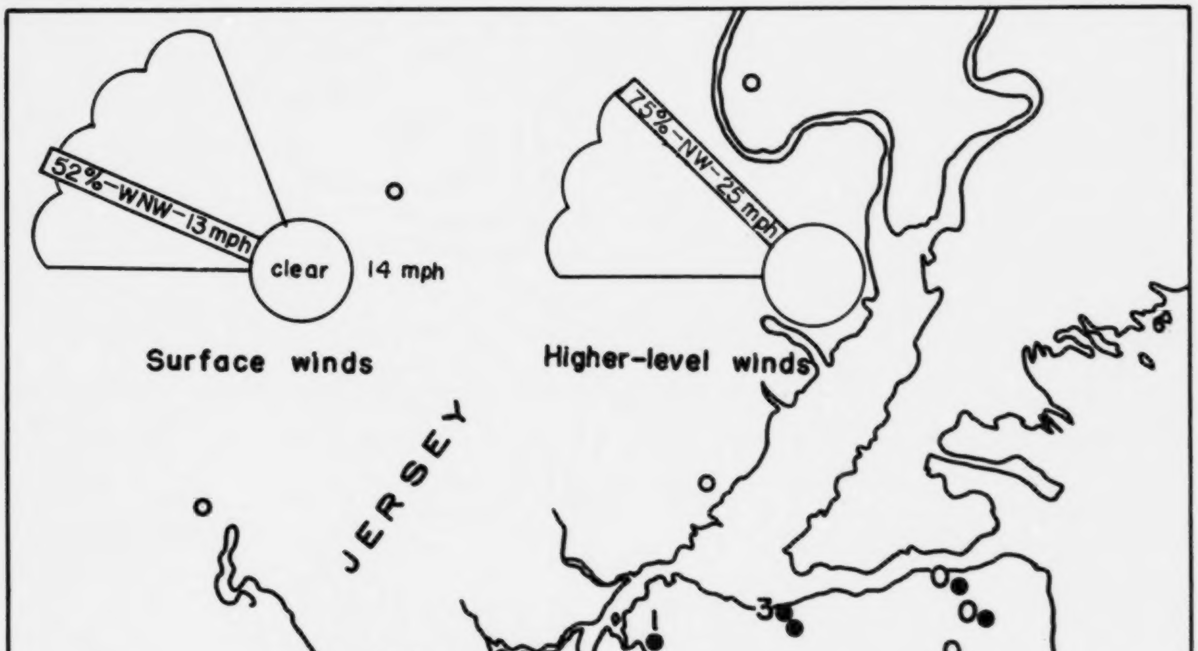

52%-WNW-13 mph
clear
14 mph
Surface winds
75%-NW-25 mph
Higher-level winds
NEW JERSEY
Linden
480 grams
8:00-8:30 P.M.
(16 gm./min.)
EN ISLAND
3
1
0
0
0
0
3
3
1
1
0
2
0
6
0
0
0
0
0
13
2
7632
6
1035
24
3361
344
0
4
1
0
0
3
0
10
100
1000
RUN No. VI
July 1, 1957

Figure 8

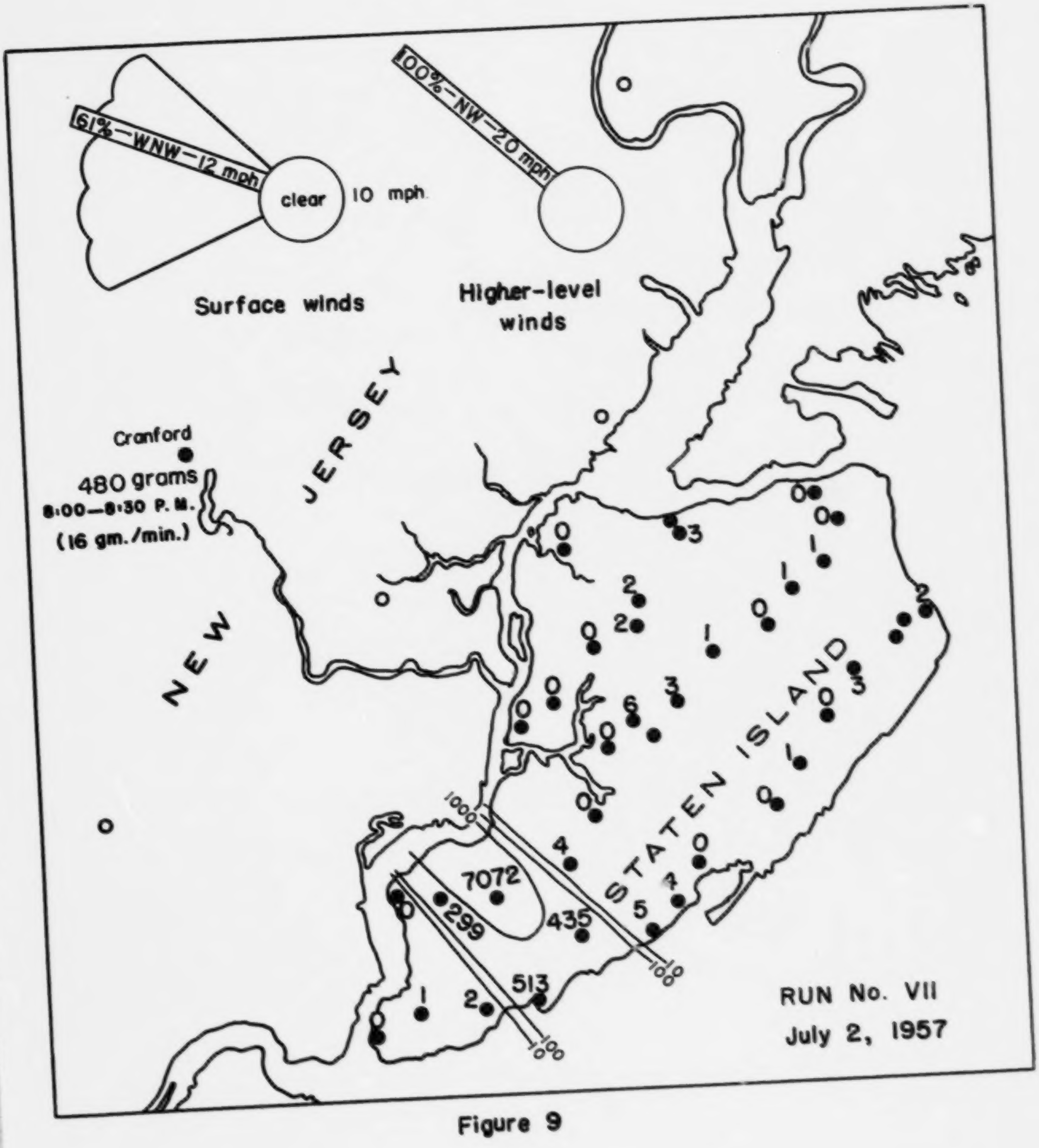

61%—WNW—12 mph
clear
10 mph.
Surface winds
100%—NW—20 mph
Higher-level winds
NEW JERSEY
Cranford
480 grams
8:00—8:30 P.M.
(16 gm./min.)
STATEN ISLAND
7072
299
435
513
1000
100
10
RUN No. VII
July 2, 1957

Figure 9

isothermal from 6650 to 7000 feet. Path of tracer can be followed across the low portion of Staten Island. Note the curvature of the path, this may be related to topography. Unexplained counts at stations 21b (36 particles) and 14 (11 particles) are probably contamination. (Figure 10).

Run No. X - July 15, 1957. Neutral stability, subsidence inversion based at 7300 feet. Only 240 grams of tracer material used, because the supply was depleted. The path followed by the fluorescent particles is rather narrow and clearly defined. Recovery was heaviest in the upwind sampling arc, particularly at station 33. (Figure 11).

Run No. XI - July 22, 1957. Unstable in lowest 100 feet, then stable to 5600 feet; near neutral stability above 5600 feet. Amount of tracer used in this and following tests was resumed at 480 grams. Note the apparent southeastward shift of the tracer path as it crossed the ridge line. The dispersal pattern cannot be adequately explained on the basis of wind records and topography. Particularly perplexing is the initial path of the tracer, which appears to have been in a direction just a little south of eastward, while weather stations in the area (including the Staten Island one) were recording NW to NNW winds. The latter half of the flight path across Staten Island conforms well with the recorded

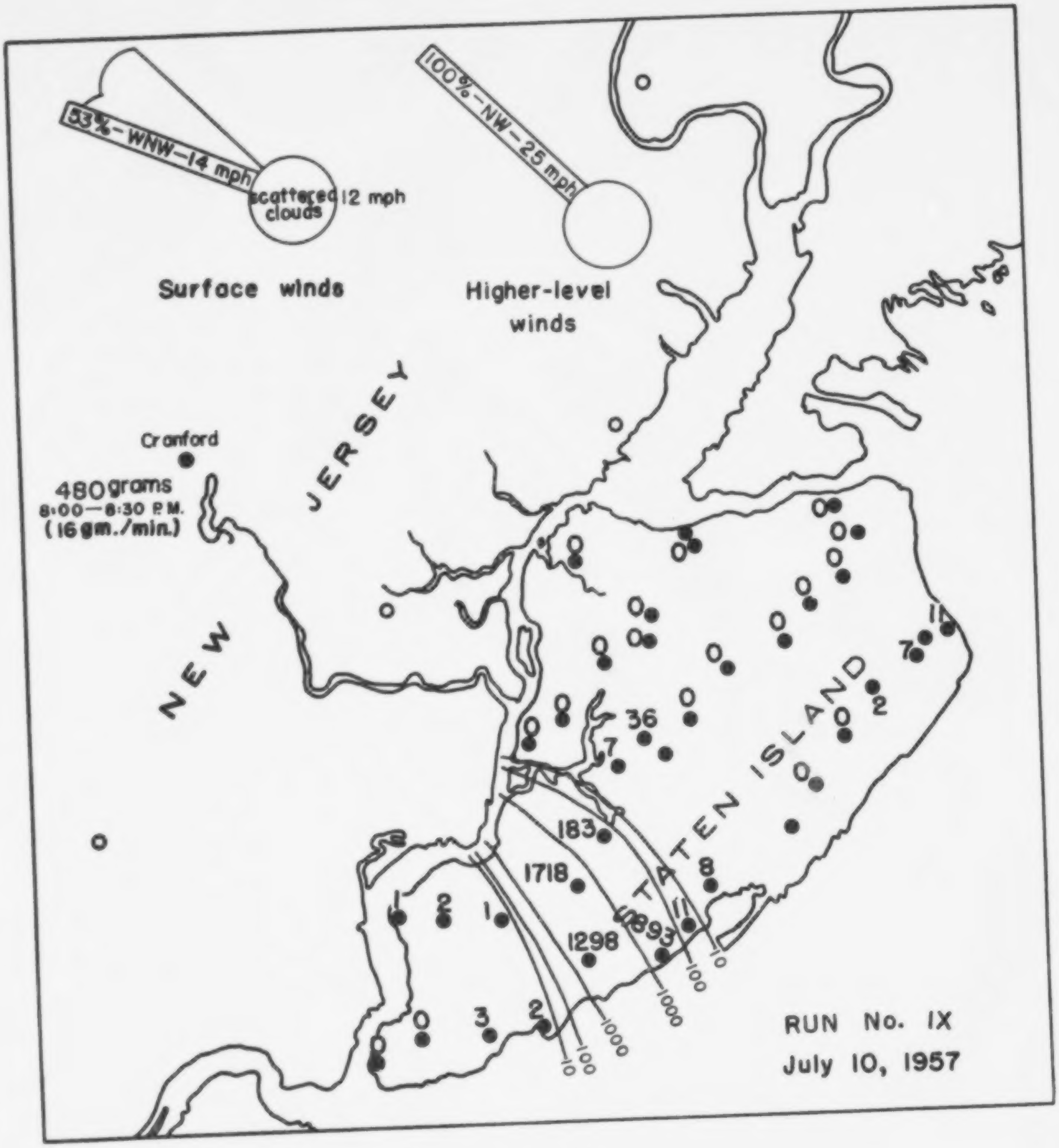

53%-WNW-14 mph
scattered clouds
12 mph
Surface winds
100%-NW-25 mph
Higher-level winds
NEW JERSEY
Cranford
480 grams
8:00—8:30 P.M.
(16 gm./min.)
TATEN ISLAND
36
7
183
1718
1298
1893
11
8
2
7
11
1
2
1
0
3
2
10
100
1000
RUN No. IX
July 10, 1957

Figure 10

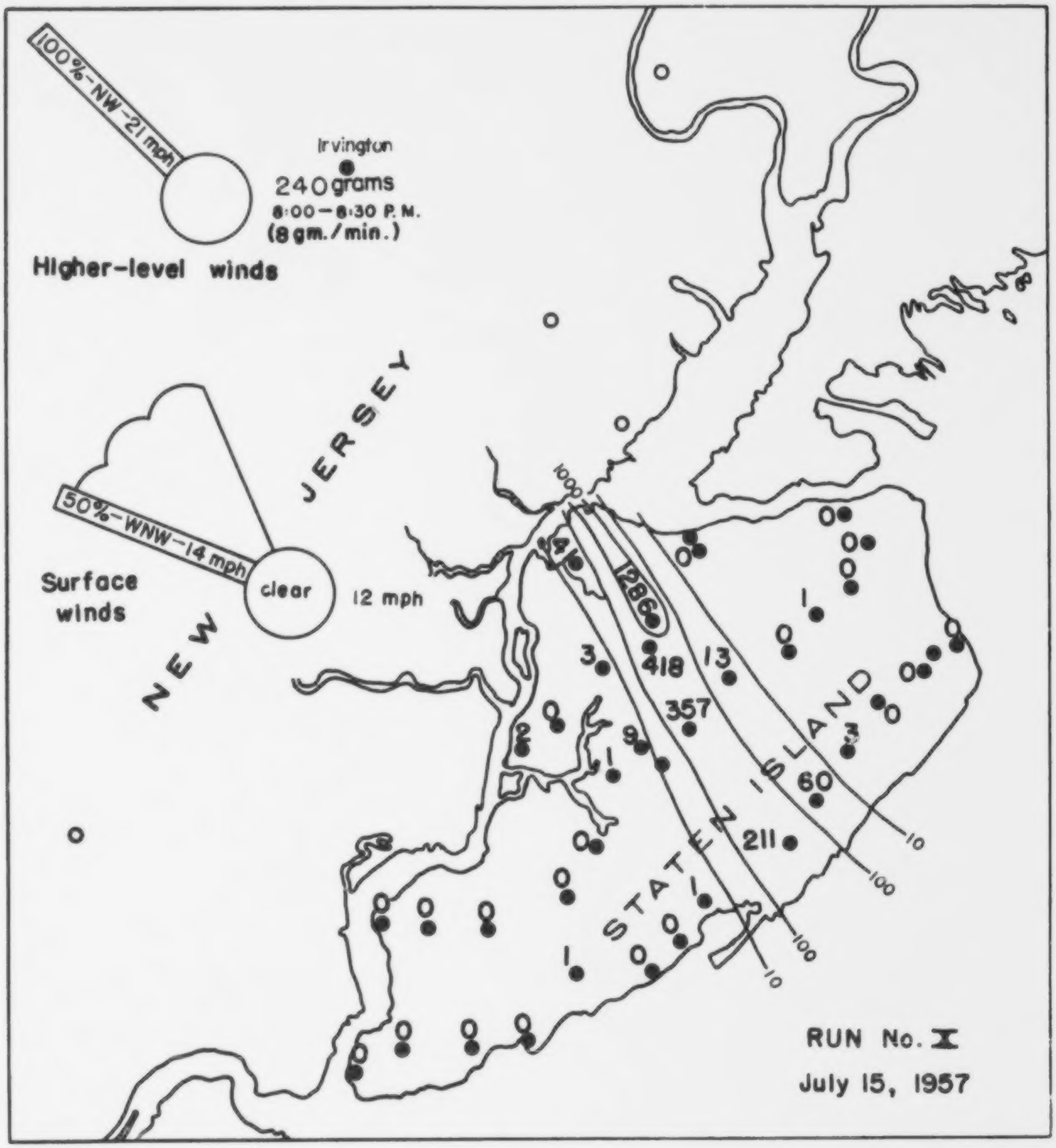

100%-NW-21 mph
Higher-level winds
Irvington
240 grams
8:00 – 8:30 P. M.
(8 gm./min.)
50%-WNW-14 mph
clear
12 mph
Surface winds
NEW JERSEY
STATEN ISLAND
1000
141
1286
418
357
211
60
13
9
3
1
0
10
100
RUN No. X
July 15, 1957

Figure 11

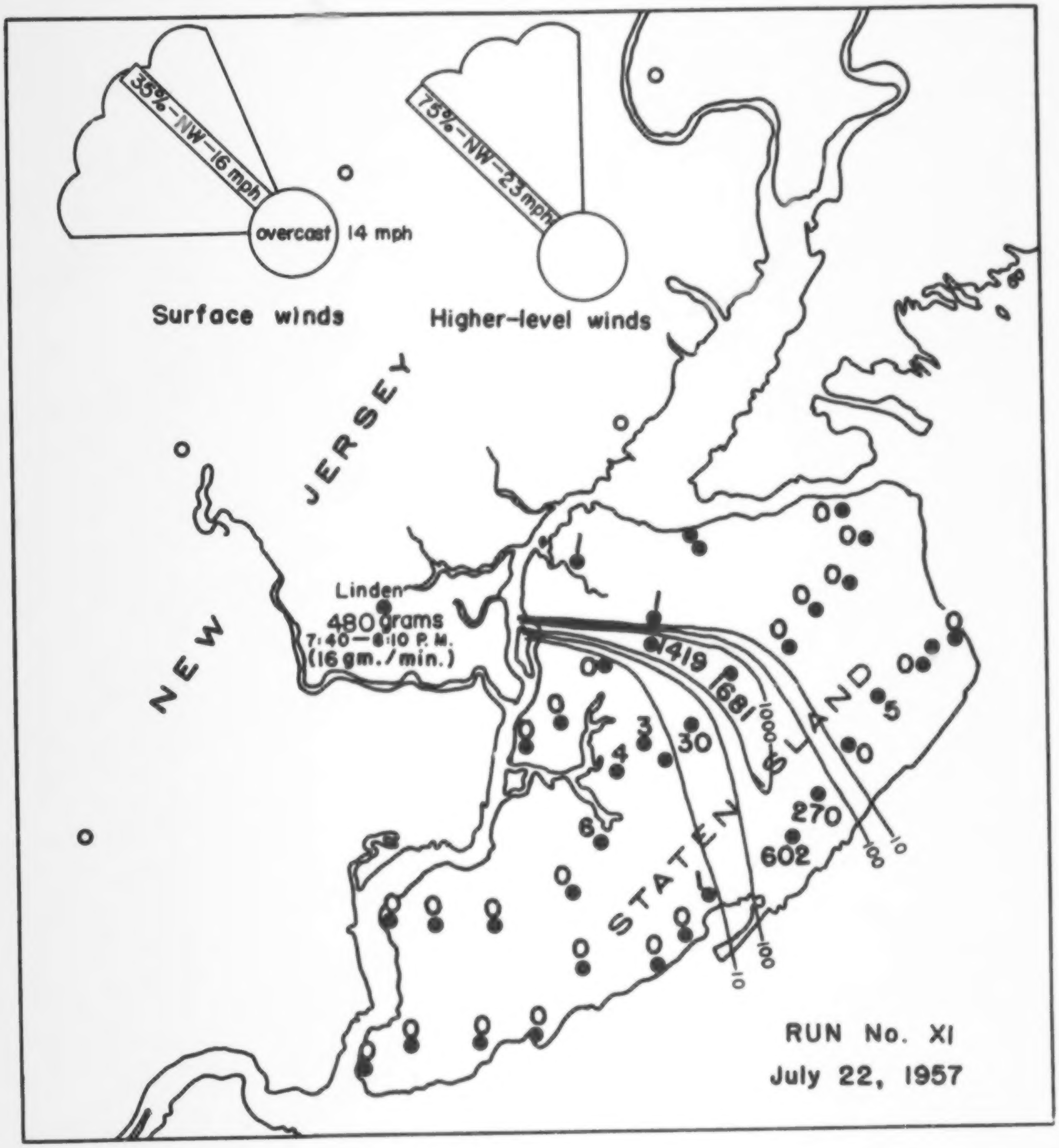

35%-NW-16 mph
overcast
14 mph
Surface winds
75%-NW-23mph
Higher-level winds
NEW JERSEY
Linden
480 grams
7:40—8:10 P.M.
(16 gm./min.)
1419
1681
1000
100
10
3
30
4
6
5
270
602
STATEN ISLAND
RUN No. XI
July 22, 1957

Figure 12

wind direction. (Figure 12)

Run No. XII - July 23, 1957. Weather conditions approached the ideal for a tracer test: light wind, and stable air. Although there was only a marginal chance of success, it was decided to attempt a test. Winds were so light as to be variable, however, and the test was unsuccessful. All filters were negative.

Run No. XIII - July 24, 1957. No meteorologist on duty. Project Officer decided to conduct test on the basis of Weather Bureau Office's general prediction of north winds. Due to the sea-breeze, however, the wind shifted to an easterly direction before dissemination time.* The operator was not contacted in time to stop or postpone dissemination. All filters negative, test unsuccessful.

Run No. XIV - August 1, 1957. No data available on vertical air structure. The peak concentration of tracer particles was nearly the same in all three sampling arcs, indicating little fallout with distance, the lateral spread was somewhat greater than in most other tests.

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* This should not be inferred as being in any respect derogatory to or critical of Weather Bureau forecasting procedures or personnel, for no such implication is intended. Their normal forecasts relate to average 24 hour conditions and, understandably, do not allow for short-range shifts such as were of concern in this project. The sea-breeze phenomenon was troublesome and constantly threatened the success of tests, even when the project meteorologist was on duty

Note the apparent meandering of the easternmost 100- and 10-particle isolines. No significance is assigned the count (16 particles) at station 29. (Figure 13).

Run No. XV.- August 5, 1957. Near neutral stability to 5900 feet, stable above that. Note the rather light recovery of particles. (Figure 14). The highest count (552 particles) was recorded in the farthest downwind sampling arc. Contrast this with Run No.X in which the same dissemination point, but only one-half as much tracer material, was used, wind speed was much the same in both tests.

Run No. XVI - August 6, 1957. Due to predominance of the sea breeze, predicted westward shift of wind did not materialize. Test unsuccessful.

Run No. XVII - August 12, 1957. Unstable to 200 feet, stable above 200 feet. The forecast was WNW, but the actual predominate wind direction was NW, with the Staten Island Airport showing NNE. Thus, only the samplers in the southwestern tip of Staten Island were positive. The main path followed by the tracer was rather distinct and well defined. (Figure 15).

Run No. XVIII - August 27, 1957. Near neutral stability to 7400 feet, inversion of 6°F from 7400 to 8100 feet. As forecast, the predominate wind direction was NW and it was expected that the tracer would travel generally across the central portion of Staten Island. However, only three samples from the

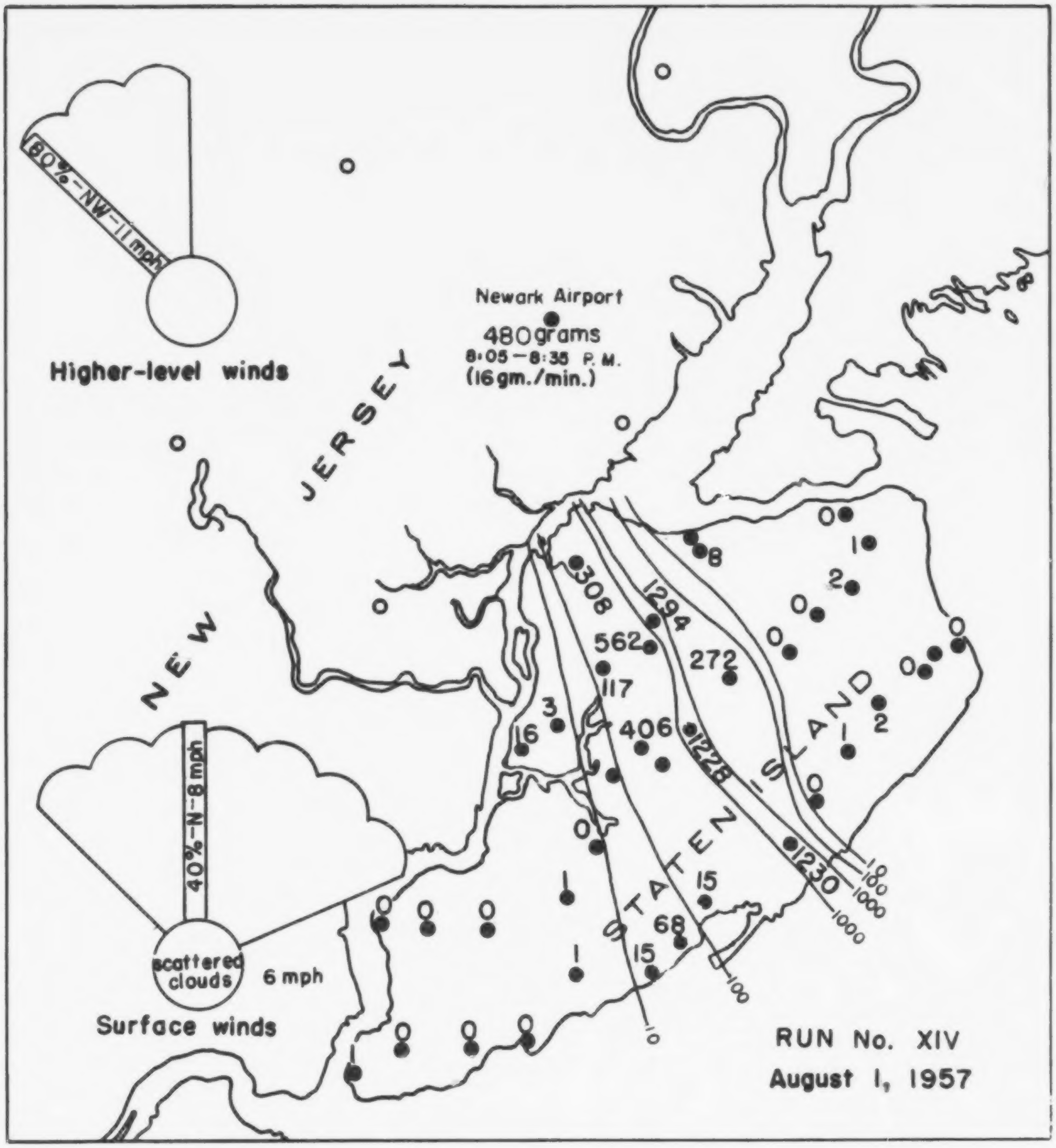

80%-NW-11 mph
Higher-level winds
Newark Airport
480 grams
8:05 – 8:35 P.M.
(16 gm./min.)
NEW JERSEY
40%-N-8 mph
scattered clouds
6 mph
Surface winds
STATEN ISLAND
308
1294
562
272
117
3
16
406
1228
1230
8
15
68
15
10
100
1000
RUN No. XIV
August 1, 1957

Figure 13

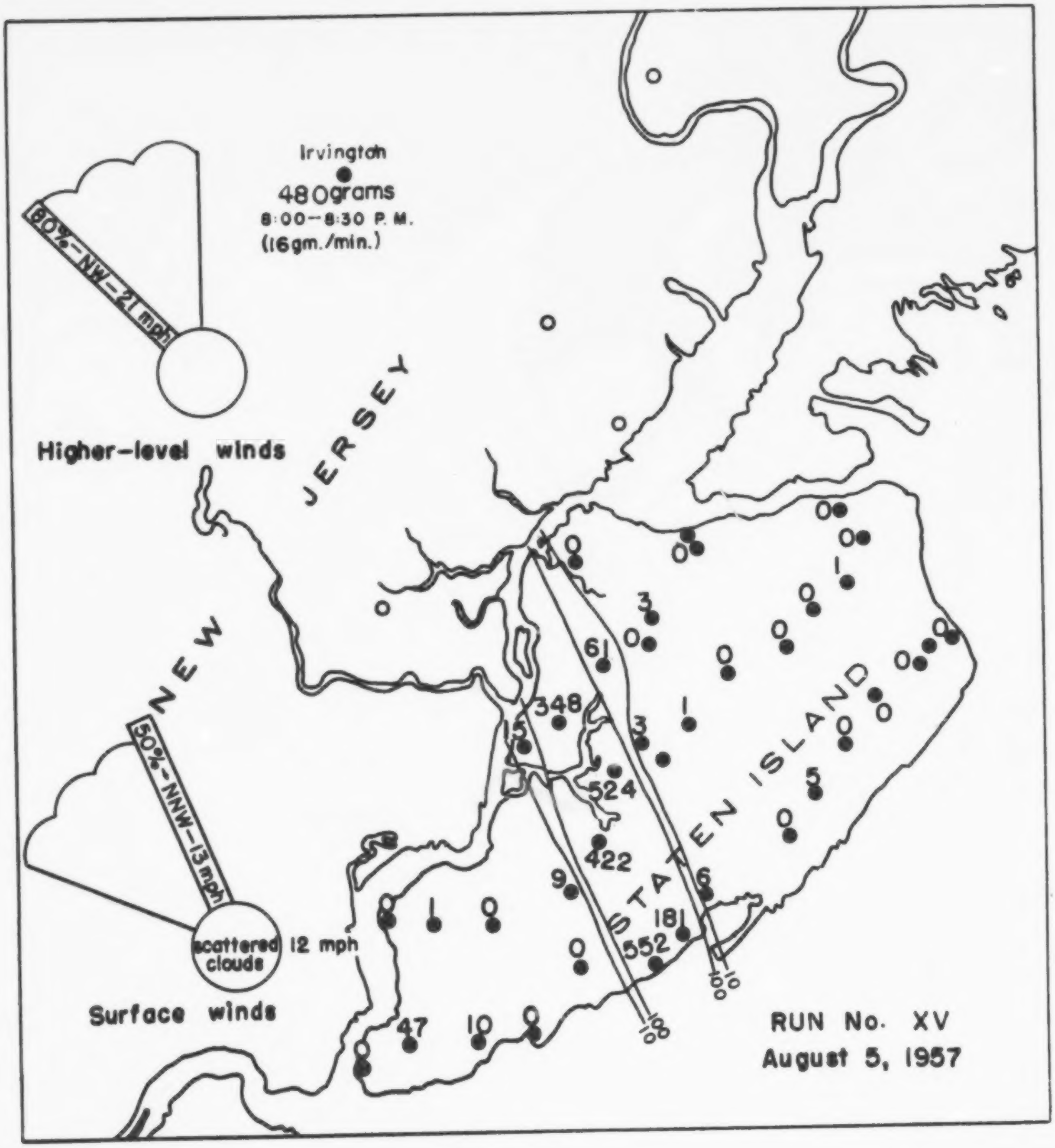
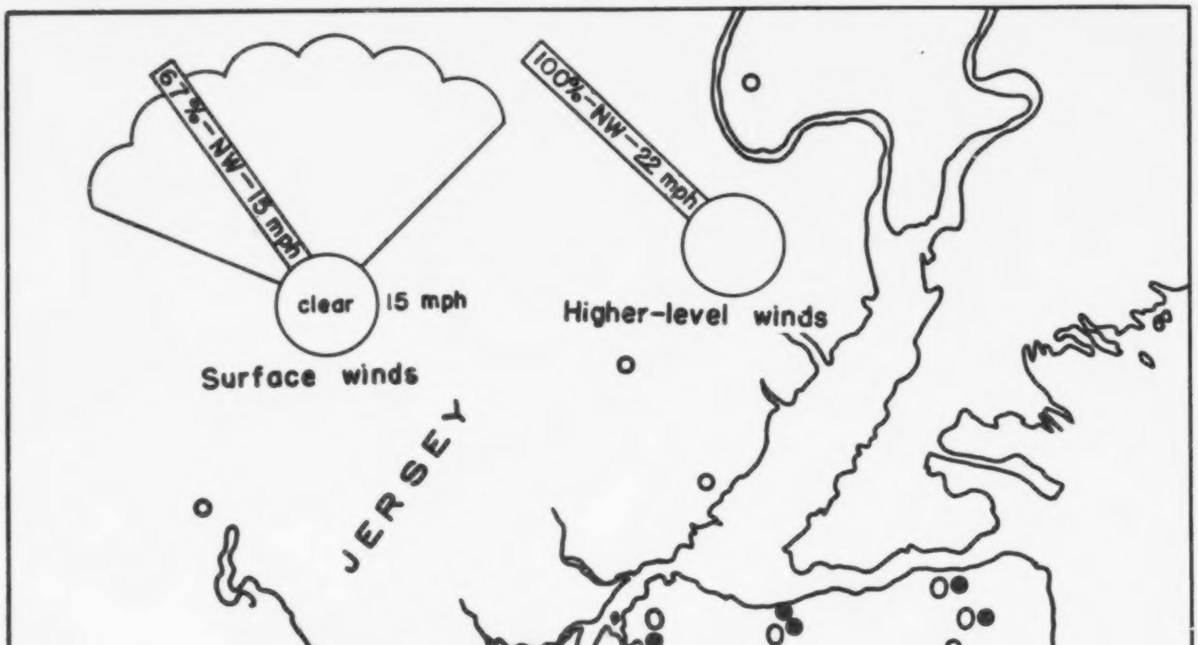

Irvington
480 grams
8:00—8:30 P. M.
(16gm./min.)
80%-NW-21 mph
Higher-level winds
NEW JERSEY
50%-NNW-13 mph
scattered clouds
12 mph
Surface winds
STATEN ISLAND
348
524
422
552
181
61
47
10
RUN No. XV
August 5, 1957

Figure 14



RUN No. XVII
August 12, 1957

Figure 15

southwestern tip of the island were significantly positive and the dispersal path is unusually distinct. (Figure 16). The influence which affected the dispersal and travel of the tracer in this manner is unknown.

Run No. XIX - September 3, 1957. Filters were put in place, but tracer material was not released due to failure of communications between the headquarters and the operator of dissemination equipment.

Run No. XX - September 5, 1957. Stable to 800 feet, neutral stability to 5400 feet, and stable above that. Based on a forecast of W to WNW winds, tracer material was disseminated at Plainfield, New Jersey, about 14 miles from the heart of Staten Island. The wind speed was low and a slight shift in the predominate wind direction to WSW apparently carried the tracer material north of the sampling area. At any rate, all filters were negative and the test was unsuccessful.

Run No. XXI - September 11, 1957. Inversion of 4°F from surface to 900 feet; neutral stability to 5400 feet, isothermal stability to 6300 feet, and 4° F inversion to 7100 feet. Wind speed was low. These were the most favorable atmospheric conditions encountered throughout this phase of the project and probably account in large measure for the unusually high count (18,500

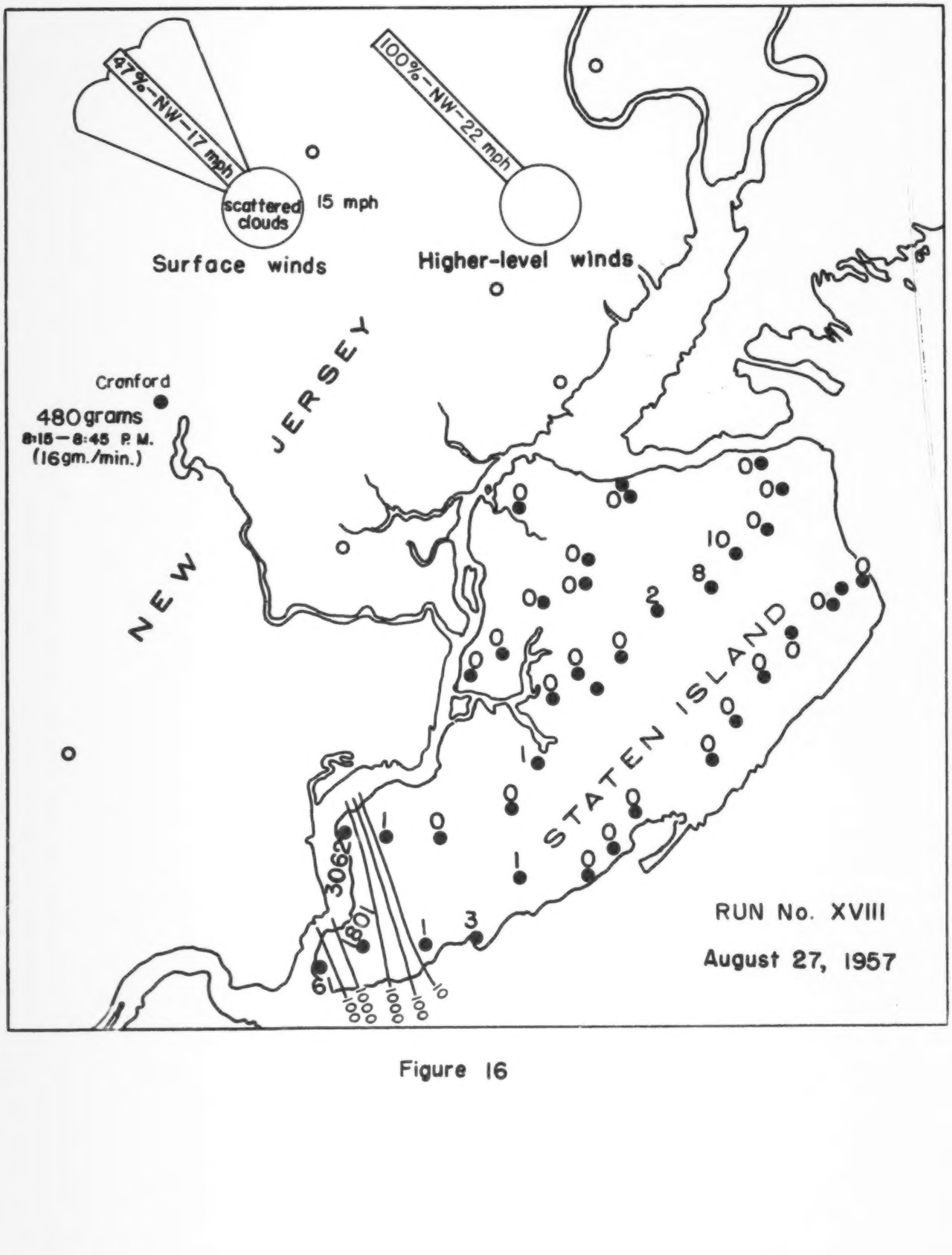

47%-NW-17 mph
scattered clouds
15 mph
Surface winds
100%-NW-22 mph
Higher-level winds
NEW JERSEY
Cranford
480 grams
8:15—8:45 P.M.
(16gm./min.)
STATEN ISLAND
10
8
2
1
1
1
1
3
3062
1801
61
1000
1000
100
10
RUN No. XVIII
August 27, 1957

Figure 16

58-C

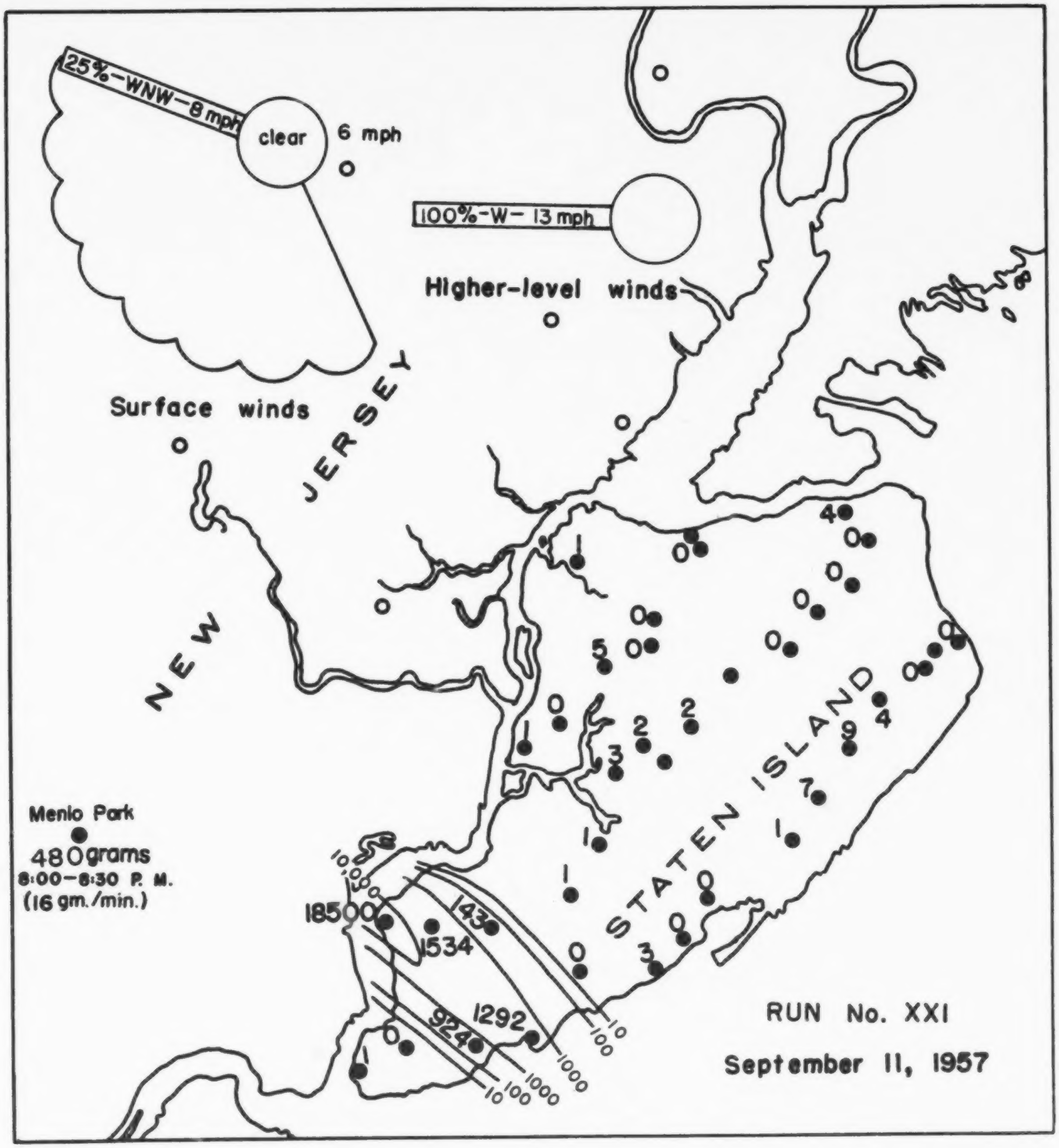


Figure 17

particles) obtained at station 15, the nearest upwind sampler. This is over twice as great as the next highest count obtained throughout the project. The dispersal path was sharply defined and crossed only the southwestern tip of Staten Island. (Figure 17)

Discussion of Results

Field operations in Phase I of the fluorescent-particle tracer project were conducted from May 28 to September 11, 1957. During these 3 1/2 months, on the average, only one test could be made each seven days. Discouragingly, the waiting periods between suitable wind conditions were sometimes protracted. In view of Weather Bureau records, this may be somewhat surprising, for annual average winds blow from New Jersey to Staten Island nearly three-quarters of the time. On this basis, one might have expected that tracer tests could have been made on an average of three days out of any four.

Seasonal variation, however, reduced the chances of favorable winds. Tests were made only during the' evenings, so nocturnal modifications reduced even further the possibility of success. Allowing for periods of precipitation, weekends, holidays, and other non-work days, what appears at first to be a rather poor performance record becomes quite comprehensible and in accord with expectation.

Accurate prediction of wind direction was essential to the success of tests. Dissemination points were five to 15 miles from the heart of Staten Island, and a few degrees' shift in wind direction would have resulted in missing the sampling area completely. Despite the difficulties associated with precise forecasting on a relatively small scale, few tests were unsuccessful due to this problem. The sea breeze was particularly bothersome. It was largely unpredictable, occasionally in direct opposition to the general gradient; even in retrospect, its predominating influence was sometimes difficult to understand.

Favorable wind direction was the only test criterion; no attempt was made to limit operations to times of temperature inversions, atmospheric stagnations, and other conditions normally associated with serious air pollution episodes. In general, the well-known effects of air pollution, such as smoke and odors, were not readily discernible; and, in fact, no test was made under sharp, severe inversion conditions.*

* Route captains and sampling-site volunteers often expressed surprise when tests were announced, because "there's no smog in the air tonight." They had not been informed of the type test being made and naturally assumed that specific pollutants were being checked. Several times, when pollution was not readily detectable by sensory perception, it was even intimated that the project officer might be trying to bias results by testing when there was little or no pollution in the air!

Nevertheless, small amounts of an identifiable simulated pollutant were dispersed in the air at five separate points in the State of New Jersey and significant concentrations of the material were recovered on Staten Island in the State of New York. Clearly, this demonstrates the interstate-transfer potential of air pollutants, and it is necessary only to apply the findings to actual emissions to arrive at estimates of the seriousness of the problem.

In view of the tremendous number of individual fluorescent particles rendered airborne in New Jersey during each test, it might appear that the number recovered in Staten Island was insignificant. For purposes of illustration, however, consider Run No. IV on June 19, 1957. During this test, 480 grams of tracer material was released at Menlo Park, about 10 miles from the heart of Staten Island.

Samples from stations 6 through 14, in the farthest downwind sampling arc in Staten Island, were positive and contained a total of 1830 fluorescent particles. These nine stations were spread along a line approximately six miles long, measured normal to the mean recorded wind direction. The mean surface wind speed was 14 miles per hour.

The total volume of air passing by these nine stations within six feet of the ground (considered to be man's normal living zone) was:

$$\frac{(6\ \text{mi})(6\ \text{ft})(14\ \text{mph})(5280\ \text{ft/mi})^2(28.3\ \text{liters/cu ft})}{60\ \text{min/hr.}}$$

$$= 6.63 \times 10^9\ \text{liters/minute.}$$

Each sampler was operated at the rate of 12.5 liters per minute, so that the total volume of air sampled by the nine stations was 9 x 12.5 = 112.5 liters per minute. Since 1830 particles were recovered by the 9 samplers, the total number of particles passing these stations within six feet of the ground is approximated as:

$$1830 \times \frac{6.63 \times 10^9}{112.5} = 1.08 \times 10^{11}\ \text{particles.}$$

The number of particles released was (480 grams) x $(3 \times 10^{10}) = 144 \times 10^{11}$ particles. Therefore, the percentage of the released particles which passed the farthest downwind sampling arc in Staten Island, within six feet of the ground, is estimated to be:

$$\frac{1.08 \times 10^{11}}{144 \times 10^{11}} \times 100 = 0.75\%$$

Similar computations* for the central arc indicate that 2.69% of the dispersed particles passed within six feet of the ground between stations 18 and 24. The orientation of the sampling network makes it difficult in this case to arrive at a valid corresponding value for the nearest upwind arc.

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*For convenience, the following formula was derived to aid in making computations:

$$P = 0.0211\frac{MSC}{GN}$$

where G is the amount of tracer released, grams;
S is mean surface wind speed, miles per hour;
N is the number of consecutive stations in a particular arc at which positive samples were collected;
M is the lateral spread of the N stations, measured normal to mean wind directions, miles;
C is the total particle count of the N filters; and
P is the percentage of the total released particles which pass by the sampling stations within six feet of the ground.

Percentages computed for the other successful tests are given in the following table:

TABLE I

Run No.	Per Cent of Released Tracer Material Passing Each Sampling Arc in Staten Island within Six Feet of Ground		
	Upwind Arc	Central Arc	Downwind Arc
V	2.65	0.01	0.26
VI	Missed	4.23	2.27
VII	Missed	3.62	0.47
IX	Missed	0.94	1.30
X	1.67	0.39	0.36
XI	0.61	0.92	0.58
XIV	0.85	1.95	0.52
XV	0.20	0.49	0.41
XVII	Missed	2.33	2.12
XVIII	Missed	1.52	1.29
XXI	Missed	5.28	0.76

At first, these figures may seem small and, in themselves, rather unimpressive. The values assume increased significance, however, when one considers the overwhelming amounts of material emitted to the air in a densely populated, heavily industrialized area similar to that portion of New Jersey which is directly opposite Staten Island. Industrial and urban air pollutants emmissions are not measured in grams, but in tons--or hundreds, or even thousands, of tons--per day. On this basis, the tracer tests tend to demonstrate that significant amounts of pollution from New Jersey pass through Staten Island within the zone which is man's normal habitat. Depending on the particular type of pollutant, the lives and properties of residents could be affected thereby to a greater or lesser degree.

A slight topographical influence on windflow seemed to be discernible in Staten Island. There appeared to be a channeling of wind through the lowest portion of the Island, beginning at Fresh Kills on the west and leading southeasterly to the Great Kills area, and stations in the central sampling arc generally received the greatest proportion of fluorescent particles.

During several tests, the flight paths of the tracer were deflected farther southwest than would be expected on the basis of wind directions only. This is shown most vividly in Runs No. V, VII, IX, and XVIII, where the iso-lines are outside the projected range of reported wind directions. It is possible that this could be explained by trajectory analysis, but insufficient meteorological data were gathered during the project to permit intensive study along this line.

Throughout the series of tracer tests, only two stations (Nos. 27 and 28) were never significantly positive. This does not necessarily indicate that the section of Staten Island containing these two stations does not receive interstate air pollution, or even that it is rare. Tracer tests depend on the whims of the weather; with suitably chosen dissemination points and proper wind conditions, stations 27 and 28 would undoubtedly have been positive.

Exposed filters from each test were usually various shades of gray but occasional black filters were noted. While this indicates that there were varying amounts of airborne particulate matter in different sections of Staten Island, the loading generally was not heavy.

No correlation could be found between the filter shade and the recovery or number of fluorescent particles. In the case of very black filters, this suggests either that there was localized pollution in the immediate vicinity of the samplers or, if the pollution was interstate, it came from a source not in the direction of the dissemination point. A black filter usually could be traced to a known local source such as traffic, a small open fire, or an institutional incinerator.

During any test it was possible to observe microscopically many fluorescent particles other than yellow ones on the filters. These ran the gamut of the visible spectrum, but they did not interfere with assessment of the filters. Green and blue particles predominated; but occasional red, orange, violet, and white fluorescent particles were noted at times. The origin and significance of these particles were not determined, but it is suspected that they included oil mist droplets and naturally occurring fluorescent materials such as pollens, dust and plant fibers.

It was observed incidentally during field operations in Phase I that rubber deteriorated seriously after relatively short exposure to the Staten Island atmosphere. In one extreme case, near the center of the Island, the rubber tape placed over the hose splice at a sampling station was so rotted and cracked that it was worthless after only two days exposure. Subsequently, at all sampling stations, friction tape was applied over the rubber tape to protect the latter from deterioration.

Inspection also revealed that the rubber tubing at all stations, except where the pump was placed inside enclosed structures, tended to rot and crack badly at any point of stress, e.g., at the end stretched over the pump inlet, at bends, and at the end where filter holders were inserted. These observations led to the decision to conduct a cumulative rubber-cracking test for the determination of atmospheric ozone, the results of which are discussed in the overall Report of the New York-New Jersey Interstate Air Pollution Study by the Interstate Sanitation Commission.

Table 2 - SAMPLING STATIONS IN STATEN ISLAND - PHASE I

Sta. No.	Name & Address of Volunteer and location on property	Upwind Exposure	Remarks
1	William H. Conine, 28 Satterlee St., NW corner of garage	Fair	30' high trees within 35' of sampler
2	Joseph C. Sullivan, 25 Joline Ave., N. side of commercial garage	Fair	20' high trees about 40' on either side of sampler
3	James J. Corrigan, 444 Sharrott Ave., porch on N. side of residence	Excellent	No obstructions
4	Marist Fathers Novitiate, 450 Bayview Ave., N side of wagon shed at farm	Excellent	No obstructions
5	David N. Miller, 450 Arbutus Ave., W side of garage	Fair	12' high hedge 25' NW of sampler
6	Richard H. Crowe, 16 Wakefield Rd., center of large front lawn N of residence	Fair	Row of 50' high trees on W side of yard
7	Harry McCafferty, 4108 Hylan Blvd., SW corner of house	Fair	1-story building 30' W of sampler
8	Carl I Oberg Funeral Home, 3787 Hylan Blvd., shed on N side of property	Fair	Row of 10-20' trees & shrubs 50' N of sampler, 1-1/2 story building 30' W
9	Oakwood Heights Community Church, 547 Falcon Ave., NW corner of personage	Good	30' high church building 100' W of sampler
10	Jerry Megna, 2395 Hylan Blvd. W edge of lawn	Excellent	No obstructions
11	Staten Island Garden Center 18[illegible]3 Hylan Blvd., N of Garage and storage warehouse	Excellent	No obstructions

Table 2 - SAMPLING STATIONS IN STATEN ISLAND - PHASE I

Sta. No.	Name & Address of Volunteer and location on property	Upwind Exposure	Remarks
12	Harry L. Scott, 259 Reid Ave. NW corner of garage	Excellent	Few scattered small trees, none closer than 50'
13a	Rocco Ameduri, 176 St. Johns Ave., SW corner of garage	Poor	Sampler sheltered by steep hill, adjacent house, and several tall trees; used for first 5 tests only
13b	John V. Russo, 19 Roderick Ave., NE corner of house	Excellent	No obstructions
14	U. S. Quarantine Station, Bay St., Rosebank, gate house at SW corner of property	Good	Tall trees about 50' to W
15	Socony Mobil Oil Co., Port Socony, SW corner of main gate house	Excellent	No obstructions
16	Hans J. Jacobsen, 143 Clay Pit Rd., NW corner of house	Poor	Tall trees on all sides of sampler; only available volunteer in the area
17	Joseph Biship, 1448 Woodrow Rd., NW corner of blacksmith shop	Very Good	30' high trees about 100' N of sampler
18	Frank A. Hauber, 210 Sheldon Ave., W side of garage	Good	Two 50' trees about 50' N of sampler
19	William Bojanowski, 135 Annadale Rd., N edge of lawn	Excellent	Bushes 15-20' high about 50' W of sampler
20	Charlie's (later Harry's) Drive-In Restaurant, 2990 Richmond Ave., NW corner of restaurant	Excellent	No obstructions

Table 2 - SAMPLING STATIONS IN STATEN ISLAND - PHASE I

Sta. No.	Name & Address of Volunteer and location on property	Upwind Exposure	Remarks
21a	Patrick Rooney, 400 Richmond Hill Rd., W side of house	Good	Large tree 25' N and another 35' S of sampler; used first test only; moved at owner's request
21b	August Dinger, 174 Richmond Hill Rd., SW corner of stable	Excellent	No obstructions
22	Herman Schmidt, 863 Rockland Ave., W side of shed adjoining greenhouse	Very Good	Row of 15-20' high trees 50' W of sampler
23	Steve LaRusso, 280 Bradley Ave., W side of house	Excellent	No obstructions
24	George Uhrig, 116 Lortel Ave NE corner of garage	Excellent	No obstruction
25	New York City Department of Parks, Clove Rd., W side of office building	Excellent	No obstruction
26	New York City Department of Parks, Victory Blvd., NW corner of Silver Lake greenhouse	Good	12' high hedge about 40' NW of sampler
27	Albert Rovegno, 72 Brighton Ave., SW corner of house	Fair	25' tree 30' W of sampler; sheltered by hill to NW
28	Sailors Snug Harbor, Richmond Terrace, NW corner of maintenance warehouse	Excellent	No obstruction
29	Roy Herrick, 4380 Victory Blvd., center of yard on E side of house	Excellent	May have been slight sheltering by house

Table 2 - SAMPLING STATIONS IN STATEN ISLAND - PHASE I

Sta. No.	Name & Address of Volunteer and location on property	Upwind Exposure	Remarks
30	Frank J. Filipowicz, 4117 Victory Blvd., SE side of store	Poor	Sampler sheltered by trees, store and 2-story house next door; only volunteer located in vicinity
31	Helen R. Mulligan, 3587 Victory Blvd., W side of house	Very Good	Bushes and several small trees 50' SW of sampler
32	Willowbrook Greenhouse, 1031 Richmond Ave., Porch on W side of house	Fair	30' trees about 25' either side of sampler; row of tall trees across street to W
33	Fred Baumann, 1414 Richmond Ave., S of greenhouse	Very Good	Several 15' trees about 30' W of sampler
34a	Edward Ringel, 25 Morningstar Rd., side of house	Fair	Row of 2-story houses 100' W of sampler, across the street; used first 5 runs only; moved at owner's request
34b	Port of New York Authority Bayonne Bridge, N side of office	Excellent	Bridge plaza higher than surroundings; no obstructions
35	Port of New York Authority Goethals Bridge, NW side of office	Excellent	Toll booths about 20' high 50' WNW of sampler

PHASE II

Scheduling

While there had been little doubt concerning the assignment of top priority to the Staten Island investigation, selection of the next testing area required rather careful consideration. By the time Phase I was underway, it became apparent that there would be time to conduct no more than one of the other planned phases. Since the objective of the tracer study was to investigate the interstate transfer of pollutants in both directions, either Phase II or III had to be chosen.

Past records were consulted in an effort to determine whether one of these two phases was more importune than the other. New Jersey residents had not consistently charged that interstate air pollution was a problem. There had been, through the years, a few scattered complaints of pollution blowing from New York, but reports were meager, sporadic, and not particularly enlightening.

Socio-economic factors tended to indicate that the area of New Jersey most likely to receive significant interstate air pollution from New York would be the counties of Hudson and Bergen, which lie across the Hudson River opposite Manhattan. Therefore, second priority was given the phase which involved dissemination of tracer material in Manhattan and sampling in New Jersey.

Meteorologically, May to October was recommended as the most favorable period of the year during which to conduct Phase II. Owing to the late start and protracted waiting periods between runs in Phase I, however, operations in the Manhattan-to-New Jersey phase did not begin until October 16. Experiences with unfavorable wind direction were much the same as in the first phase, the resultant periods of inactivity from one test to the next caused particular discouragement and anxiety as the ominous study deadline approached. Operations were terminated at the end of November, after only four tests had been conducted. Wind directions were far from ideal during the tests; two tests were made under decidedly marginal conditions and their results were disappointing.

Dissemination Points

This project was aimed primarily at demonstrating windflow and pollutant-dispersal patterns, rather than at investigating specific pollution sources. In view of the time shortage, dissemination points were selected to provide this information as quickly as possible and with a minimum of difficulty. Selected sites were along the Hudson River where the lofty buildings of Manhattan would be least likely to interfere. Through the cooperation of the New York City Department of Parks, arrangements were made to use the parking areas along the Henry Hudson Parkway at 96th Street, 155th Street, and Dyckman Street. A fourth dissemination location was provided by the Department of Sanitation at its incinerator plant, Gansevoort Street and the Hudson River.

As in Phase I, dispersal of the tracer was from the truck roof. The New York City Police Department provided police protection for the operator and equipment during dissemination

Sampling Network

In planning the sampling network in New Jersey, topography of the area was the dominant consideration.

Along the Hudson in New Jersey, the relatively flat and narrow strip of waterfront land is devoted mainly to docks, wharves, railroad yards and factories. Not far from the river, palisades rise abruptly to 300 feet and higher. The plateau atop the palisades selected to provide this information as quickly as possible and with a minimum of difficulty. Selected sites were along the Hudson River where the lofty buildings of Manhattan would be least likely to interfere. Through the cooperation of the New York City Department of Parks, arrangements were made to use the parking areas along the Henry Hudson Parkway at 96th Street, 155th Street, and Dyckman Street. A fourth dissemination location was provided by the Department of Sanitation at its incinerator plant, Gansevoort Street and the Hudson River.

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Along the Hudson in New Jersey, the relatively flat and narrow strip of waterfront land is devoted mainly to docks, wharves, railroad yards and factories. Not far from the river, palisades rise abruptly to 300 feet and higher. The plateau atop the palisades is over a mile wide and is lined with contiguous cities and towns. At the western edge of the plateau the cliffs drop, almost as abruptly as they rose on the east, to the undeveloped meadows and marshlands in the plain of the Hackensack River and its tributaries. Farther west, on higher ground, populous areas are resumed.

In an effort to evaluate what effect, if any, the palisades might have on windflow patterns, one line of samplers was established on the low ground along the Hudson and another group was installed on the plateau. These sampling routes stretched from Jersey City to Englewood Cliffs, a distance of about 14 miles. In the northern portions, where the palisades are very pronounced, the two sampling lines were less than one-fourth mile apart, at the southern end, in relatively flat terrain, the lines were separated by more than 1 1/2 miles.

A third sampling line, two to four miles west of the plateau route, was set up in an attempt to trace the flow of pollutants after crossing the river flats. Only the northern half of this line, from Teaneck to East Rutherford, was established. Data to be gained by completing the southern half--in either the desolate meadow area or the populated area farther west--were deemed incommensurate with the practical difficulties of locating volunteers and conducting field operations.

In each sampling route, the distance between samplers was approximately one mile.

In contrast to the almost bucolic simplicity of Staten Island, the area of Hudson and Bergen Counties is sophisticated and cosmopolitan. This section of New Jersey presents a conglomeration of intermingled residential, commercial, and industrial properties. Single-family homes and lofty multi-unit apartment houses, light to heavy industries of various sorts, business houses, towering hotels and office buildings, desolate meadow areas with rural-type highways, and populous cities with crowded traffic arteries--all of these were encountered in the Phase II sampling area.

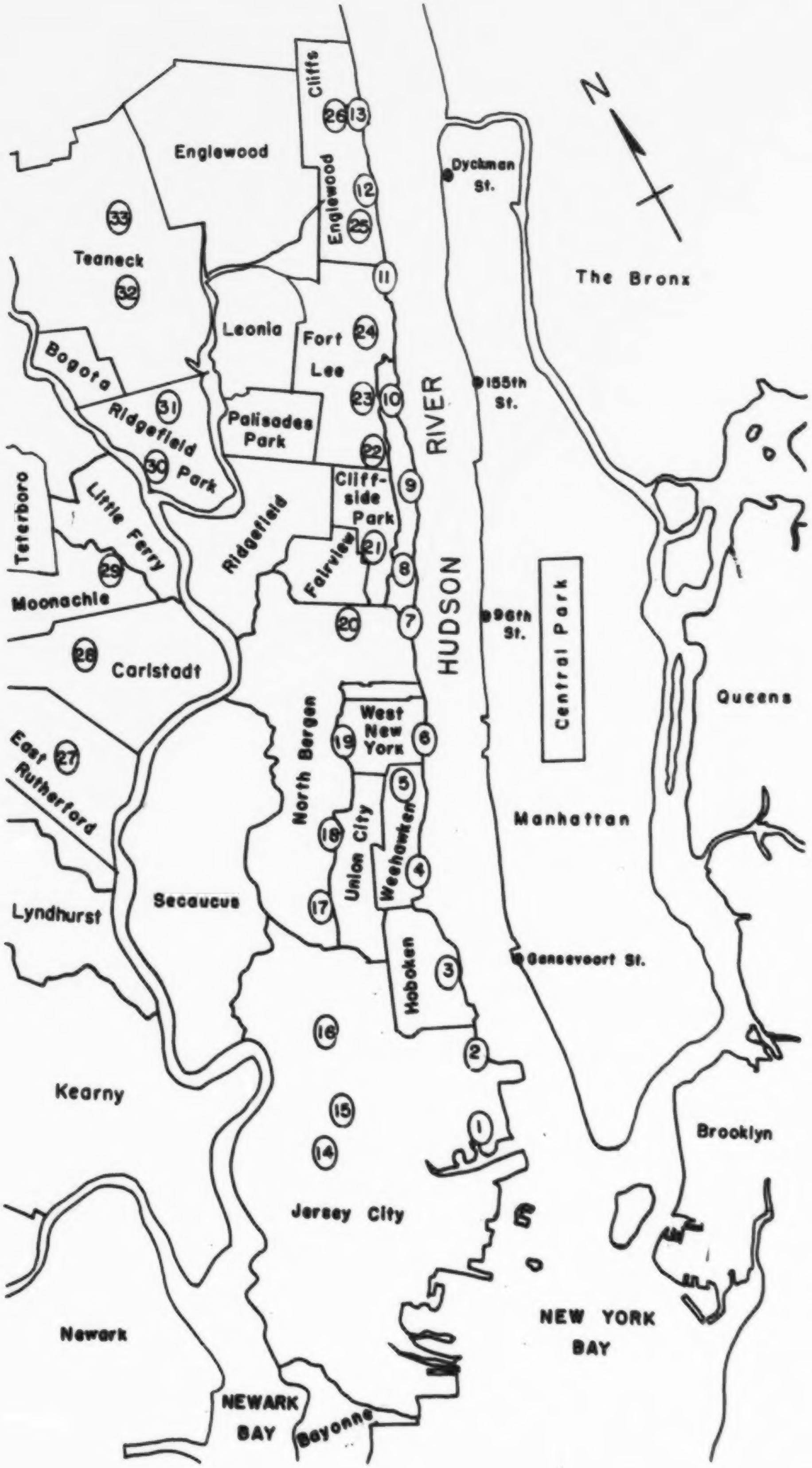
The preponderance of tall buildings, particularly in certain parts of the sampling network, made it desirable that both vertical and horizontal development of the area be considered in the planning. Samplers were placed at various heights from a few feet above the ground to the roofs of tall structures, in order to detect any elevational difference in movement or concentration of the tracer.

Recruitment of volunteers who would permit the establishment of sampling stations on their properties was considerably more complicated, expensive, and time consuming than it had been in Phase I. There was no central agency, similar to the Staten Island Air Pollution Control Association, that was intimately familiar with the entire area. Over a dozen cities and towns were involved. Individual contacts had to be made in nearly every case, although local health officials were helpful in certain jurisdictions. Most of the properties had absentee owners or managers, which necessitated extra correspondence, personal trips, or telephone calls. More than five man-months of effort was expended in enlisting the 33 sampling-site volunteers.

The sampling station locations and designations are shown in Figure 18, and a detailed list of the stations is included in Table 3 (pages 86-89).

Meteorological Coverage

Weather information from Newark and Teterboro airports was teletyped routinely to the Weather Bureau where it was available, along with data from the New York stations, for use by the project meteorologist in forecasting and in supporting test results. It was believed that data from these stations were adequate


N
Cliffs
Englewood
Englewood Cliffs
Dyckman St.
Teaneck
The Bronx
Leonia
Fort Lee
Bogota
Ridgefield Park
Palisades Park
155th St.
HUDSON RIVER
Teterboro
Little Ferry
Ridgefield
Cliffside Park
Fairview
Moonachie
96th St.
Central Park
Carlstadt
Queens
West New York
North Bergen
East Rutherford
Manhattan
Union City
Weehawken
Lyndhurst
Secaucus
Hoboken
Gansevoort St.
Kearny
Brooklyn
Jersey City
NEW YORK BAY
Newark
NEWARK BAY
Bayonne
1
2
3
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15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33

Figure 18

and representative of conditions in the sampling area, therefore, a separate project meteorological station was not established in this phase.

Except for the first two tests, actual forecasting during this phase was done from the Weather Bureau Office in Cincinnati, Ohio - the home station of the project meteorologist. Information was teletyped daily to the Project Officer in New York. Accuracy of the forecasts was not significantly reduced due to the remote location of the meteorologist. By means of the Weather Bureau communications facilities, he had in Cincinnati virtually the same information available to him in Manhattan.

Field Headquarters

Space for field headquarters was provided, through the cooperation of the Mayor's office, in the basement of the Public Library building on 60th Street in West New York, New Jersey. All operations concerned with direction and conduct of Phase II of the project were carried on from this field office which, fortunately, was located near the center of the sampling area.

Sampling Operations

Part-time personnel were obtained through the personal efforts of the Health Officer of Cliffside Park, New Jersey.

Field operations were conducted in a manner identical with those described under Phase I, with the following minor changes:

(1) Route captains were responsible for the operation of from 3 to 7 samplers, depending on the complexity of the particular route and the required transportation time,

(2) One-half hour, instead of one hour, was added to the theoretical flight periods from disseminator to sampler, to arrive at shut-off times. This arbitrary adjustment was made because distances were shorter than they had been in the previous phase.

All times given for Phase II operations were Eastern Standard Time.

Test Results

Following is a chronological history of the tests made in Phase II. Individual maps for the separate tests contain the same information as included on those for the previous phase, except that surface-wind directions and speeds shown on Phase II maps do not include data from the Staten Island Airport Station.

Run No.I October 16, 1957. Surface inversion of 5° F to 800 feet, near neutral, but stable, to 5600 feet, stable above 5600 feet. The tracer material was deflected considerably eastward from the path which would have been predictable on the basis of observed wind direction alone (Figure 19). Note the counts at station 28 (38 particles) and station 31 (14 particles), whereas the other stations in the farthest west sampling route were virtually negative. Filters from all stations except two (and malfunctioning samplers were suspected in those cases) were observed macroscopically to be blacker than any that had been collected throughout the entire Phase I. Particulate loading on filters was so great that it was feared there might have been obscuration of fluorescence.

Run No.II - October 31, 1957. No information on vertical temperature gradient. Marginal wind direction, with little chance of a successful test, had been forecast by the meteorologist. Nevertheless, in view of the approaching project deadline, it was decided to take advantage of the remote possibility. Only two filters (stations 1 and 2) at the southern end of the sampling network were significantly positive (Figure 20). Test unsuccessful.

Run No. III - November 13, 1957. Stable air from surface to 1000 feet. Meteorological conditions, in general, resembled those in Run No. I, and a similar eastward deflection of the tracer cloud was noted (Figure 21). The same dissemination point was used in both runs, but the amount of fluorescent material

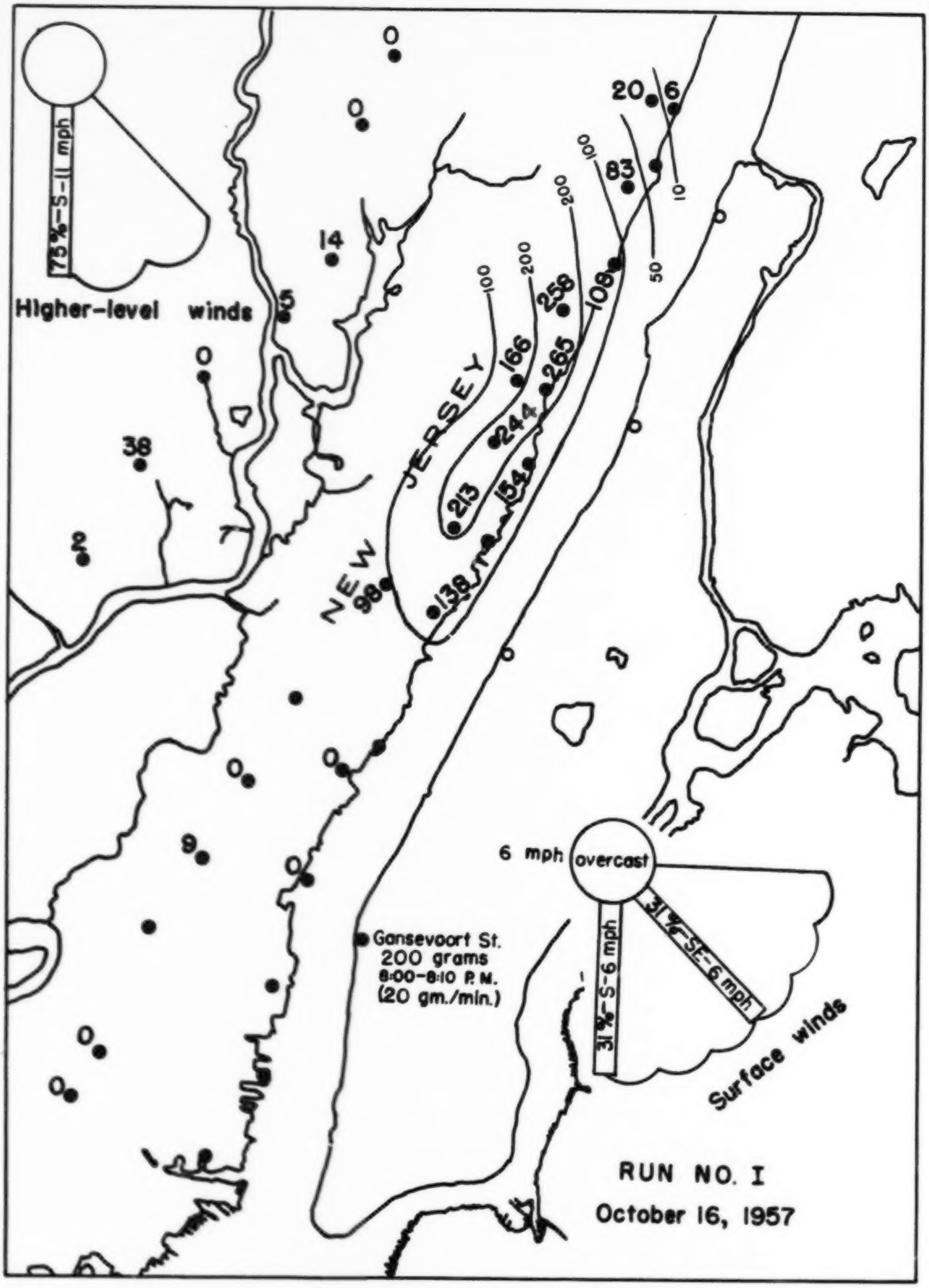
75%-S-11 mph
Higher-level winds
0
0
20
6
83
10
100
50
14
200
100
200
5
258
108
0
166
265
NEW JERSEY
244
38
213
154
2
98
138
0
0
0
9
0
0
0
Gansevoort St.
200 grams
8:00-8:10 P.M.
(20 gm./min.)
6 mph
overcast
31%-S-6 mph
31%-SE-6 mph
Surface winds
RUN NO. I
October 16, 1957

Figure 19

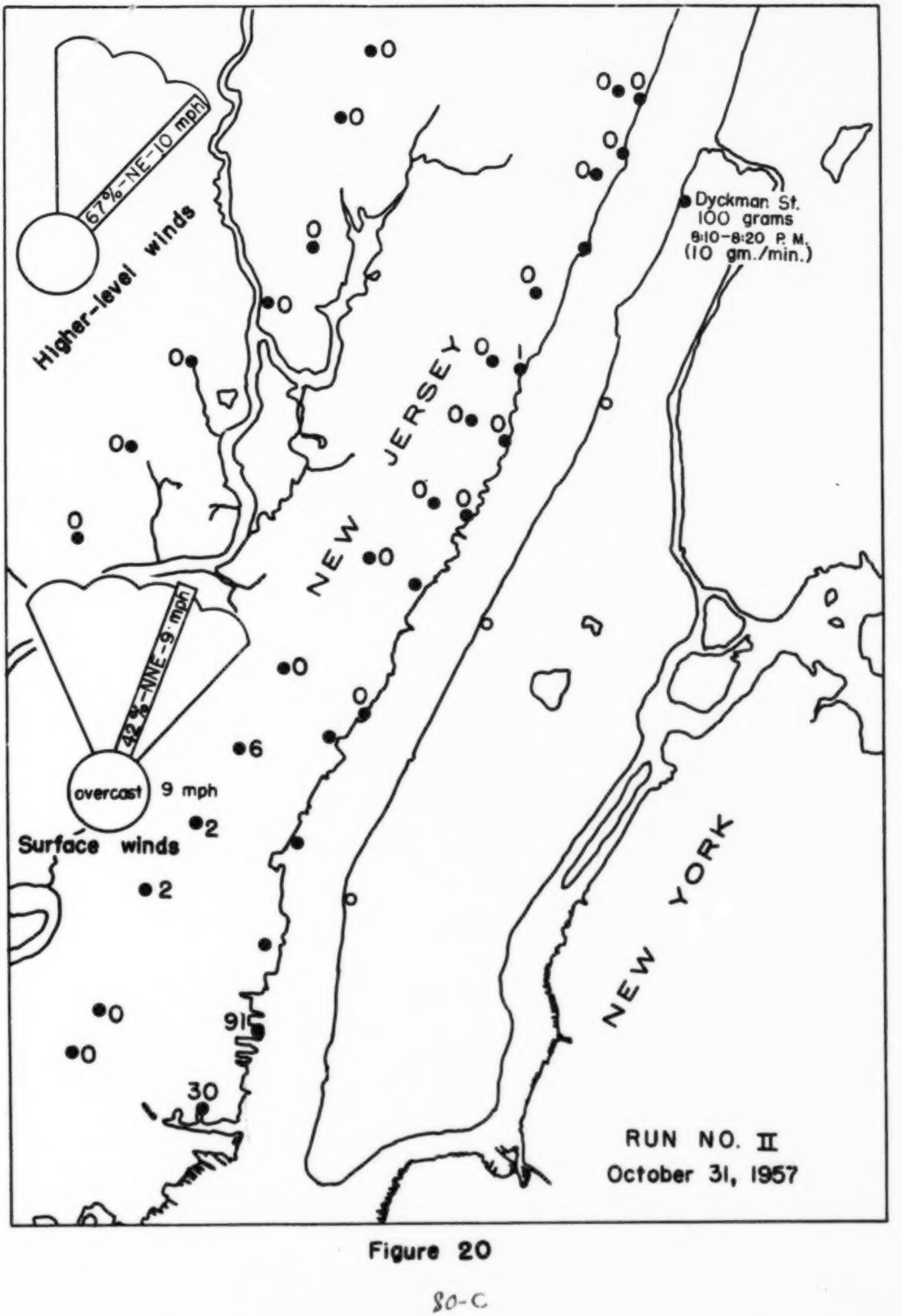
67%-NE-10 mph
Higher-level winds
Dyckman St.
100 grams
8:10-8:20 P. M.
(10 gm./min.)
NEW JERSEY
42%-NNE-9 mph
overcast
9 mph
Surface winds
NEW YORK
6
2
2
91
30
RUN NO. II
October 31, 1957

Figure 20

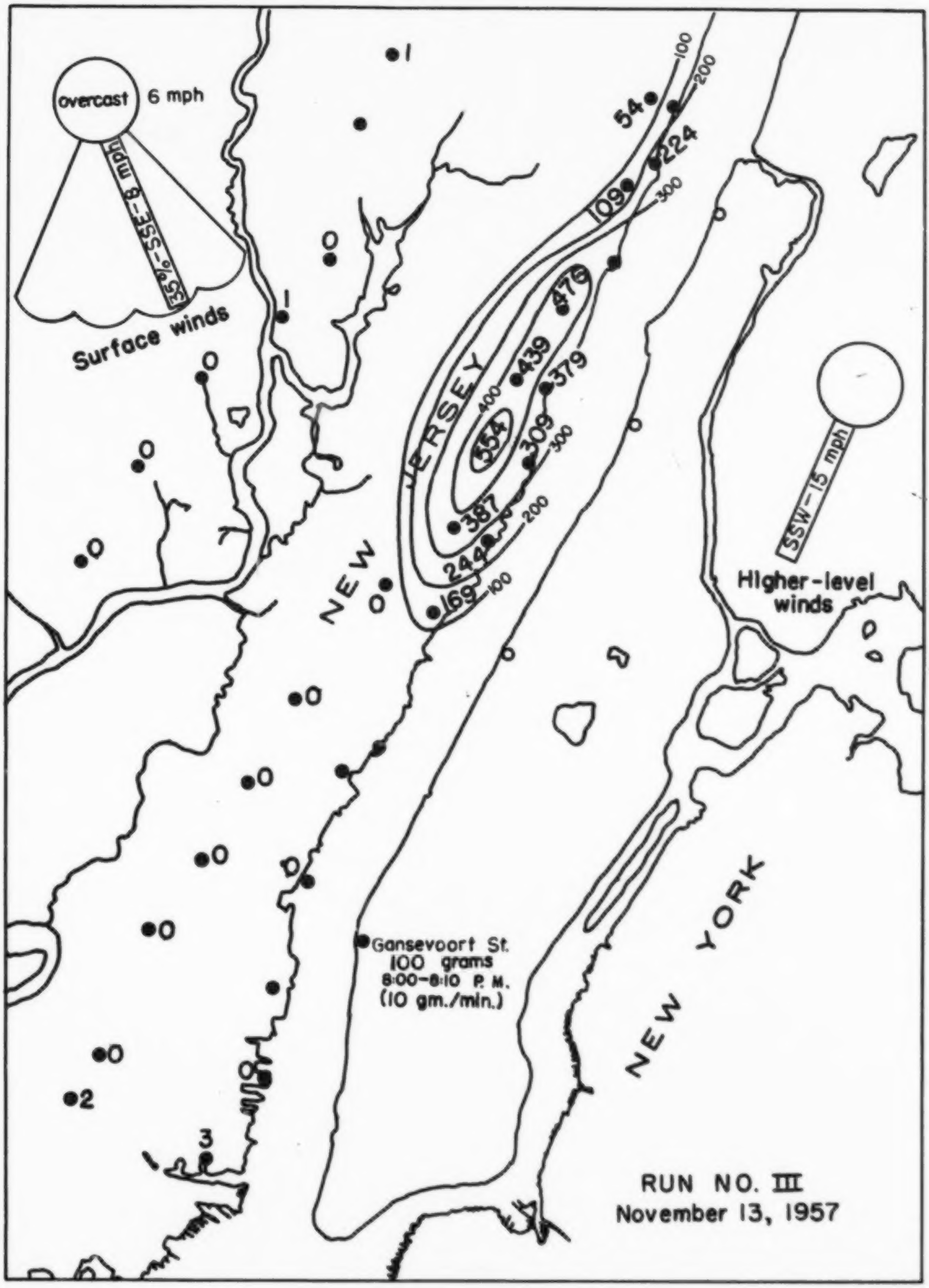
overcast
6 mph
35% - SSE - 8 mph
Surface winds
SSW - 15 mph
Higher-level winds
NEW JERSEY
NEW YORK
1
1
0
0
0
0
0
0
0
0
0
2
3
54
224
109
476
439
379
354
309
387
244
169
100
200
300
400
300
200
100
Gansevoort St.
100 grams
8:00-8:10 P.M.
(10 gm./min.)
RUN NO. III
November 13, 1957

Figure 21

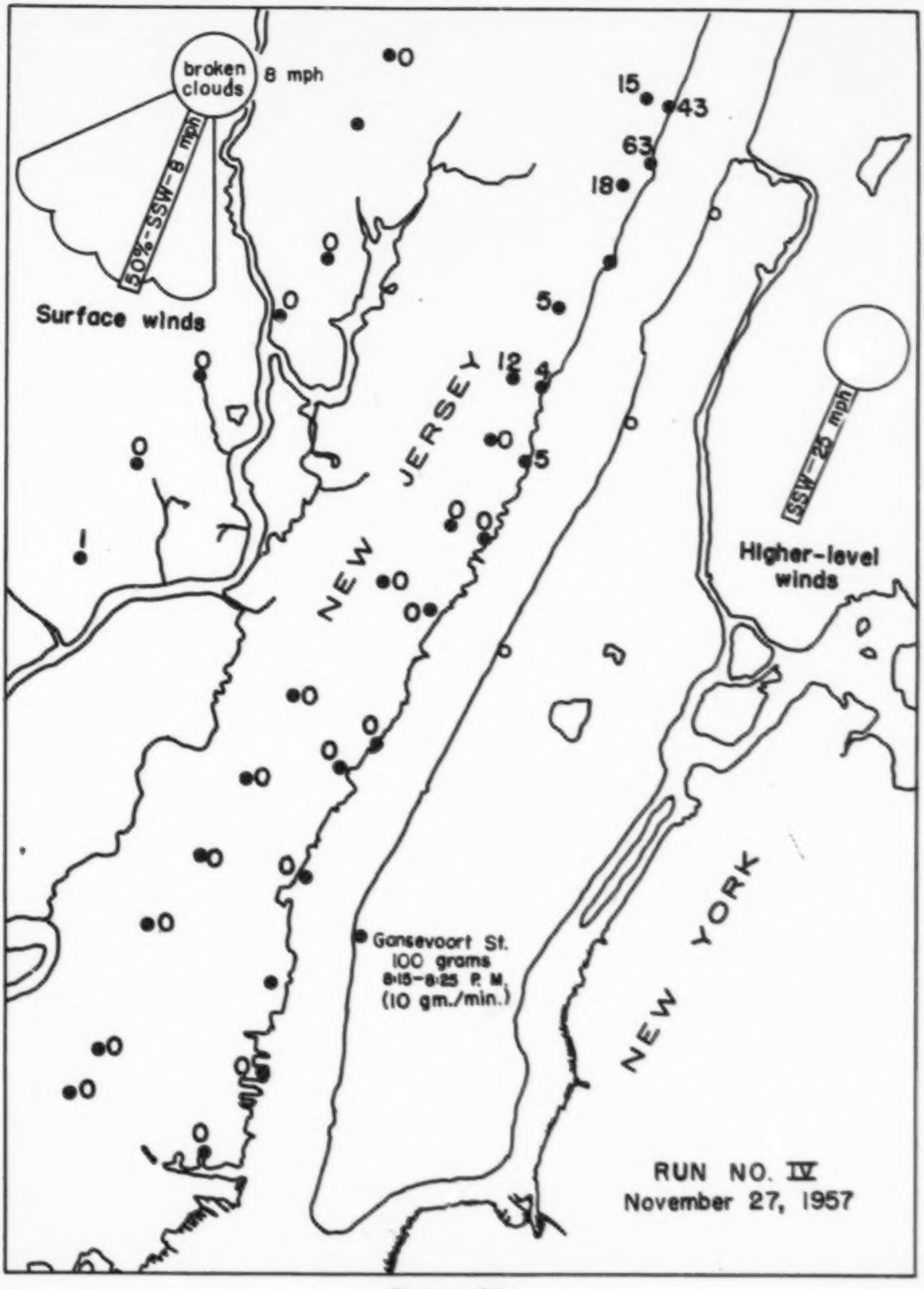

Figure 22

80-E

dispersed in the first run was twice as much as in this test.

Run No. IV - November 27, 1957. Stable air from surface to 500 feet, unstable from 500 feet to 1000 feet. The forecast was marginal and the test was unsuccessful, only a few stations at the northern end of the sampling network were positive (Figure 22).

Discussion of Results

Experiences with adverse wind conditions were even more discouraging in Phase II than they had been in Phase I. Although the samplers were completely installed and the route captains were trained and oriented by October 3, easterly component winds were not prevalent until the sixteenth of the month. Field operations were terminated at the end of November to allow time for assessment of samples, evaluation of data, and preparation of the final report. (Authorizing legislation specified that the Commission's report was due by February 1, 1958)

Within this period, only four tests could be undertaken, and an average of fourteen days was encountered between tests. None of the tests was conducted under ideal wind conditions. The easterly component of the winds was never well developed during the tests conducted in this phase of the project.

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Consequently, only the northernmost and extreme southern dissemination points in Manhattan could be used, and the farthest west sampling route in New Jersey was never reached by the tracer material. During Runs No.II and No.IV the forecasts were decidedly marginal, and the results were unsatisfactory.

Since Runs No. I and No. III were the only two which yielded reliable data, the drawing of broad, definite conclusions would be unwarranted. However, a brief discussion of the results and presumptive findings may prove interesting and enlightening in several respects.

Meteorological conditions during Runs No. I and No.III were similar in many respects, and the same dissemination point (Gansevoort Street) was used in each case. The amount of fluorescent tracer material used in Run No. I (200 grams) was twice that dispersed in Run No. III (100 grams), recovery of the tracer in Run No. III, however, was roughly twice as great as the counts found in Run No. I. The reason for this seeming paradox is not readily apparent, but it demonstrates the difficulty of attempting to predict downwind pollutant dispersal on the basis of the common meteorological parameters alone.

Practically the same sampling stations were positive in both runs. Greatest recovery of the tracer

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material was at the higher-level sampling stations, i.e., along the top of the palisades.

Within a particular sampling route, however, no significant difference was found between fluorescent-particle recovery by adjacent low-level and high-level samplers. This demonstrates the thorough mixing of the tracer in the atmosphere and gives some indication of the vertical as well as the horizontal diffusion.

The palisades exerted a definite influence on windflow, channeling the air masses along the Hudson River, as evidenced by the deflection of the tracer material farther eastward than the recorded wind directions of the area would indicate. This shift is most noticeable in Run No.I, but it is also demonstrable to a degree in Run No. III. In Run No.I, if the outside limits of the recorded surface winds are projected in a northerly direction from the dissemination point, it will be noted that the path of the tracer falls almost entirely outside this range.

It is regretted that additional tests could not be conducted, under a variety of wind conditions, to permit more thorough investigation and evaluation of this interesting effect.

Computation of the percentages of emitted tracer material which passed within six feet of the ground in New Jersey, similar to those percentages computed for Phase I, would be of little value because of the orientation of the positive sampling stations with respect to the dissemination point. In addition such computations would be complicated by the fact that samplers were located at various heights in Phase II, whereas they were uniformly at five feet above ground in Phase I. Nevertheless, recovery of the tracer in New Jersey was indicative of the dispersal of interstate air pollutants from New York. Under different wind conditions, the dispersal would probably have been more extensive and the recovery considerably higher.

In this phase, the particulate loading on filters was generally very great. Macroscopically, it was noted that practically all of the samples were shades darker than the ones collected in Phase I, in fact, Phase II filters without heavy particulate loading were usually traced to malfunctioning pumps. It should be pointed out, however, that the atmosphere was more stable during Phase II tests than it had been during Phase I, this would tend to confine all air pollutants to a lower level.

Because of the experience in earlier tests, rubber tubing at the sampling stations was constantly checked for deterioration. In the 2 1/2 months that samplers were exposed to the atmosphere, however, no excessive cracking of rubber was noted and no tubing required replacement.

As in Staten Island, fluorescent particles other than the yellow ones disseminated during the the tests were noted on the New Jersey filters. The concentration and variety of such particles in Phase II were not, however, so great as they had been in the first phase.

Table 3 - SAMPLING STATIONS IN NEW JERSEY - PHASE II

Sta. No.	Name & Address of Volunteer and Location on Property	Upwind Exposure	Remarks
1	Rodermond Industries, Foot of Henderson St., Jersey City, east bulkhead of repair dry dock	Very good	5' above ground 15' above water 6' fence 40'E
2	Erie Railroad, Pier 8, Jersey City, roof	Excellent	65' above water, nearest pier 200' N.
3	Stevens Institute of Technology, roof of maintenance shed	Good	6' above ground, adjacent to 1-story building; tree 25' NE
4	Erie Railroad, Dock D, Weehawken, eastern edge of pier roof	Excellent	60' above water, nearest piers 200' N and 400' S.
5	New York Central Railroad, Freight Station Weehawken, E. side of Roof	Excellent	50' above ground, no obstructions
6	New York Central Railroad, Pier 9, West New York, 50' from W. end of pier	Excellent	5' above water level, 4 traveling gantry cranes on pier
7	Vergona Brothers, 55 River Road, Edgewater, E. side of garage on shed roof	Fair	5' above ground, 4-story research laboratory 250'E.
8	Edgewater Sewage Treatment Plant, River Road, Edgewater, E. side of office	Excellent	5' above ground, no obstructions
9	Pumphouse #2, Edgewater Sewerage System, Halliard Ave. & River Road, Edgewater, S.E. Corner of building	Very good	5' above ground, 1 story garage 50' N.

Table 3 - SAMPLING STATIONS IN NEW JERSEY - PHASE II

Sta. No.	Name & Address of Volunteer and Location on Property	Upwind Exposure	Remarks
10	Pumphouse #1, Edgewater Sewerage System, Orchard St. & River Road, Edgewater, S.E. corner of building	Very good	5' above ground, semi-circle of tall trees 50' from site
11	Ross Dock, Palisades Interstate Park, E side of First Aid Building	Excellent	5' above ground, several 25' trees 150' NE & SE
12	Englewood Boat Basin, Palisades Interstate Park, SE corner of dock	Excellent	7' above water; no obstructions
13	Undercliff Picnic Area, Palisades Interstate Park, E side of pavilion	Very good	5' above ground, 30' tree 15' NE
14	Engine Company No. 9, Jersey City Fire Dept., Bergen & Duncan Aves., Jersey City S side of first-story roof.	Poor	20' above street; sheltered by second story to E & other surrounding buildings
15	Hotel Plaza, Journal Square, Jersey City, parapet on E roof of 7-story building	Excellent	80' above street, no obstructions
16	Frank Boehler, 3299 Hudson Blvd., Jersey City, E side of residence	Good	5' above ground, row of 2-story buildings across street, 150' E
17	Pyramid Electric Co., 1445 Hudson Blvd., North Bergen, E of gatehouse	Fair	5' above ground, 1-story buildings 20' N & S
18	Fritz Reuter Altenheim, 3131 Hudson Blvd., Union City, E of administration building	Excellent	5' above ground no obstructions
19	Public Service Gas & Electric Co., 58th & Jefferson Sts., West New York, roof of 2-story office building, E side	Excellent	30' above street, no obstructions

Table 3 - SAMPLING STATIONS IN NEW JERSEY -PHASE II

Sta. No.	Name & Address of Volunteer and location on property	Upwind Exposure	Remarks
20	Veterans Apartments, 89th St. & Bergenline Ave., North Bergen, E.side of roof, 7-story apartment house	Excellent	65' above street, no obstructions
21	Joseph Aragona, 404 Cecilia Place, Cliffside Park, SE of residence in yard	Fair	5' above ground, tall trees NE & SE of sampler
22	Joseph Vince Sunoco Station 831 Palisade Ave.,Fort Lee, NE corner of building	Excellent	5' above ground, no obstructions
23	Jerry Tarantino, 200 Elsmere Place, Fort Lee, E of residence	Excellent	5' above street, no obstructions
24	Port of New York Authority, George Washington Bridge, Fort Lee, E side of roof, 2-story office building	Excellent	30' above street, no obstructions
25	Englewood Cliffs Sewage Treatment Plant, Hudson Terrace, Englewood Cliffs, S side of property	Very Good	5' above ground, several tall trees on property, N of sampler
26	Rustic Cabin Esso Station, Route 9 W, Englewood Cliffs, SE corner of garage	Very good	5' above ground, row of trees 100 yards E.
27	Sharry's Crown Station, Route 3, East Rutherford, E. of service area	Good	5' above ground, tree 10' S, garage 50' N
28	William Reckner, 218 Washington Ave., Carlstadt, E side of barn	Excellent	5' above ground, no obstructions

Table 3 - SAMPLING STATIONS IN NEW JERSEY - PHASE II

Sta. No.	Name & Address of Volunteer and Location on property	Upwind Exposure	Remarks
29	Anthony De Grosa, 206 Park Ave., Moonachie, E.side of garage at residence	Very good	5' above ground; 1-story printing plant 100' NE
30	Park Sunoco Service Station, Route 46 & Main St., Ridgefield Park, SW corner of garage	Fair	5' above pavement, paper company plant 500' SW
31	Frank D.Fabian, 211 Overpeck Ave., Ridgefield Park, NE corner of residence	Fair	5' above lawn; trees 25' E; house wing 5' S & 15' E
32	Holy Name Hospital, Lindburgh Ave. & Teaneck Rd., Teaneck, S.E.corner of power house	Fair	5' above driveway, hospital building 50' N & E
33	Teaneck Presbyterian Church, Teaneck Rd & Church St., Teaneck, NE corner of parish house	Very good	5' above lawn, 1-story buildings across street 125' E.

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4. Perkins, W.A., P.A. Leighton, S.W. Grinnell and F.X Webster, "A Fluorescent Atmospheric Tracer Technique for Mesometeorological Research," *Proceedings, Second National Air Pollution Symposium*, Pasadena, September 1952, pp 42-6.

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6 Rosinski, J., H.E. Glaess and C.R. McCully, "Particle Size Distribution and Number of Particles per Unit Mass of Some Fluorescent Powders," *Analytical Chemistry*, vol. 28, April 1956, pp 486-90.

APPENDIX

(This is a sample copy
of the letter used to
recruit sampling-site
volunteers in Phase I.
Note that no payment
was authorized).

You have probably read in the public press that the Interstate Sanitation Commission, in cooperation with other governmental agencies, is conducting an intensive study of the interstate aspects of air pollution in the New York - New Jersey area.

In connection with this study, an invitation is extended to you as one of a select group of public-spirited citizens to cooperate with this Commission, by granting to the Commission and the governmental agencies affiliated with it in this project, your permission to install, for a temporary period, at a mutually agreeable location on the property occupied by you at the above address, certain government owned, electrically operated equipment to be used in the study. This equipment, with your permission, will be installed and operated by authorized representatives of this Commission, and will be removed by them at the conclusion of the study.

Your cooperation is invited on a voluntary basis.

You may indicate your acceptance of this invitation by signing the permissive form at the foot hereof. We assure you of our sincere appreciation for your cooperation.

Cordially yours,
INTERSTATE SANITATION COMMISSION

Seth G. Hess
Director & Chief Engineer

TO INTERSTATE SANITATION COMMISSION:

The undersigned, occupant of premises ______________________________ ______________________________ hereby accepts your invitation to cooperate in the air pollution study being conducted by you, and grants permission to you to install and maintain certain equipment at said premises for the purposes set forth in the foregoing letter.

____

(This is a sample of the letter sent
to private individuals in Phase I,
authorizing nominal reimbursement for
electrical energy consumed by samplers.
This letter was not sent to those agencies and individuals who had indicated
their desire to contribute the power
free of charge.)

Please accept the sincere thanks of this Commission for granting us permission to establish and operate an air sampling station on your property. As you probably know, the station is one of a network set up on Staten Island, as part of the New York-New Jersey interstate air pollution study, to determine the atmospheric transport of pollutants.

Although your cooperation was solicited and very generously granted on a purely voluntary basis, we have rearranged our budget so that you may be reimbursed for the electrical energy used by the sampling device. We are prepared to pay you at the rate of twenty-five cents per test run. Your check will be mailed at the conclusion of the project.

Again let me express the Commission's appreciation for your public spiritedness in this connection. We hope that this payment will in some measure reimburse you for any inconvenience our sampling program may cause you.

Very truly yours,

INTERSTATE SANITATION COMMISSION

Seth G. Hess
Director & Chief Engineer

(This is a sample copy of
the letter used in Phase II
to recruit sampling-site
volunteers. Note that it is
similar to the letter used in
Phase I, except that payment
is authorized. In the case
of public institutions and
others not desiring payment,
the Phase I letter was used.)

You have probably read in the newspapers that the Interstate Sanitation Commission, in cooperation with other governmental agencies, is conducting an intensive study of the interstate aspects of air pollution in the New York - New Jersey area.

In connection with this study, an invitation is extended to you as one of a select group of public-spirited citizens to cooperate by granting us your permission to install certain government-owned, electrically operated equipment on the property occupied by you at the above address. This equipment, with your permission, will be installed for a temporary period at a mutually agreeable location, and will be operated by authorized representatives of this Commission. It will be removed by them at the conclusion of the study.

We are prepared to reimburse you at the rate of twenty-five cents per test for the electrical energy used by the sampling device. A check will be mailed at the conclusion of the project.

Please indicate your willingness to cooperate by signing the permissive form at the bottom of the page. We assure you of our sincere appreciation.

Very truly yours,

INTERSTATE SANITATION COMMISSION

Seth G. Hess
Director & Chief Engineer

TO INTERSTATE SANITATION COMMISSION:

The undersigned, occupant of premises located at ______________________________ hereby accepts your invitation to cooperate in the air pollution study being conducted by you, and grants permission for you to install and maintain certain equipment at said premises for the purposes stated in the foregoing letter

____

INTERSTATE SANITATION COMMISSION

NEW YORK-NEW JERSEY INTERSTATE AIR POLLUTION STUDY

Route No: ________

Route Captain : ____________________

Run No: ____________________ Date: __________

Station No.	Time On	Time Off	Remarks

(This is a sample copy of the reporting form used during field tests. Note its simplicity. It was purposely kept uncomplicated, since part-time non-technical personnel were used as Route Captains.)